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INAUGURAL ADDRESS

BY THE PRESIDENT,

MR. HENRY HODGSON,

(GUIDE BRIDGE,)

DELIVERED SATURDAY, 13TH JANUARY, 1900.

In looking round for a subject upon which to address you this evening, I have been led to take one that I think is of supreme interest to us as engineers, and although it may not possess the merit of being pleasing, is yet one which, as members of this Association, and on the still higher ground as members of the community, we ought to look fairly in the face and do all in our power to turn back the tide which threatens to overwhelm us.

The title I have given to my address is, for want of a better one, "Our Position as Engineers."

There is a saying, proverb, motto, or whatever you may prefer to call it, which at one time was practically, if not strictly true, but to-day it is certainly *not* true; the saying I refer to is "England the Workshop of the World."

It is true that our export trade in manufactured mechanical articles, is still on the increase, but is the increase commensurate with the increase of the population of the World? This is probably a question that is not within the province or knowledge of any one here to answer, but, allowing that it is, it is certainly not advancing at the same rate as the increased requirements of civilisation, and the opening of new sources of trade, together with the increase of the population, and the greater numbers brought within the reach of civilisation.

We are forcibly reminded of this by the immense growth of the mechanical and industrial productions of foreign nations,

notably America and Germany, and other countries in a lesser degree. The two countries (America and Germany) are not only large producers for home consumption (and in this manner reducing their requirements from us), but they are also large suppliers to other countries, of which we at one time had the monopoly. This may not in itself be detrimental to us, and on the whole I do not think it has been, as it has undoubtedly been the means of stimulating healthy competition.

Prior to the great Exhibition of 1851, England was the world's provider in things mechanical. This Exhibition opened the eyes of the foreigners, and set them on the "*qui vive*," and from that time forth, in America and Germany and other countries, a mechanical spirit that threatens to overcome that of our own, has grown up. I am not prepared to say that the 1851 Exhibition (the first seed of what has been been a pretty prolific family) was a mistake even from a national point of view as I believe we have reaped benefits from it which are far in excess of any detriment that may have been caused to us from that event, although it, no doubt, was the stimulating cause of what has now grown into severe competition. We are all, of course, quite willing to admit in a general way that that must be right and best which does the most good to the greatest number, and we can all appreciate the force of this truth until it comes home to us individually.

The question which I draw your attention to is :—In the race for the world's mechanical requirements, are we holding our own, and, if so, are we likely to continue to hold our own ?

We do not want all the trade, for if we had all we could not execute it. Taking a backward view of the last twenty-five years, and more especially of the last ten, does the prospect before us hold out a hope that we shall maintain the foremost position in the race for the world's trade, if we continue on our present lines ? We shall, no doubt, for some considerable time

to come be the foremost, but we should not forget that, compared with any other country, we are largely industrial producers, whilst they, on the other hand, are largely engaged in agricultural production.

I am no pessimist, but I am of opinion that the condition of production will have to undergo considerable modification if we are to continue to hold the foremost place in the rank of the mechanical producers of the world. We have, within the last few years, had an invasion of mechanical work both from America and Germany, and, unfortunately, from our standpoint, there is a likelihood of this being continued. It may be said that this is only the natural outcome of the late lamentable strike in the engineering trade, and that when we have entirely recovered from the dislocation, affairs will return to their normal condition, and we shall supply our own requirements as heretofore. *Shall we?* Not unless we can, in the future, prevent any possibilities of strikes, and not until we re-organize our system of work. To the present we have been indulging in a spirit of self sufficiency. The systems upon which we have been working, whilst they have served well in the past, have been, and are, too much stereotyped. We have been, and now are working too much on the lines of the gentleman who, having sons that appeared to him to have more go-aheadedness than discretion, stipulated in his will that the business was to be continued on the old lines, with the result that soon after his death there was no business to conduct.

Many of us have seen this same idea exemplified in the case of firms who, at one time, held foremost places in the engineering world, and whose business connections warranted the supposition that they were sound and safe as the Bank of England, but who, in consequence of holding on too long and too tenaciously to the system on which they had built up their reputation, gradually declined, and ultimately disappeared

altogether. The old Lancashire saying that "there are only three generations from clogs to clogs" possesses, to my personal knowledge, and also, I have no doubt, to many of you, more than a substratum of truth. What is true of individuals is more or less true of communities.

The old and much of the present system will have to be largely modified if we are to maintain the leading position. One of the modifications, and a very important one, will have to be the relations between capital and labour; these ought, under no circumstances, to be antagonistic, and although at the present moment there is no open display, there is an undercurrent of antagonism which prevents workmen from doing all in their power to advance the interests of employers, which, in the long run, are also the interests of the workmen themselves. Man is a communist, and the success of one means, more or less, the success of many.

There seems to be an idea in the minds of many men, that the way to meet with continuous employment is to be careful not to do too much, this is one of the ideas of which their minds will require to be disabused. A better relation will have to be established between the Employer and Employé, by which the latter will only consider he has done his duty when he has done his best, and for which best he will in return reap a material pecuniary benefit.

Piecework, if it could be put on an equitable basis, and so formulated as to meet all cases, seems to me to promise a good measure of success, and in such work as lends itself to a fixed basis of prices, has proved fairly successful, but, unfortunately, there is a fly in the amber in this case. A rate or price is fixed for the production of a certain piece of work, the workman lays himself out to do his best, and in course of time becomes very expert, and earns a considerable sum weekly. Someone suddenly discovers this, and on the ground that he is earning too much,

the price is cut down, not because the price paid per article is too much, but because the man has (even though it may be a natural consequence of intelligence and practice, and the use of small appliances of his own designing) largely increased his power of production. The effect of this is to prevent the man using his best endeavours in the future, and this is eventually to the detriment both of himself and his employer. This is not an isolated case, but is one of common occurence in shops where repetition work only is the order of the day, and which must have the effect of neutralizing to a large extent the advantage which piece-working possesses if rightly administered.

There is another aspect of piecework, which so far as I can judge, must somewhat militate against the system. This is a want of elasticity to meet the varying prices of the article manufactured. If a standard price exists for the construction of any article, there is not always a standard price for the sale of that article, and the price must necessarily ebb and flow according to the demand; the cost being a fixture, but the sale price a variable one, the employer is the one who has all the advantages and disadvantages of the varying prices. If the plus and minus balance each other, this may not be very inequitable, but the ups and downs may by no means be equal, and if the down grade should be one of considerable length disastrous results may be the consequence. It appears to me that in the case of such manufactures as admit of being worked on the piece-work principle, the price paid for production should be governed directly by the price obtainable in the open market for the sale of the article so manufactured.

The piece-work system, however worked, does not meet the whole case of the relations between employer and employé between capital and labour. Some system more comprehensive will, sooner or later, have to be adopted, (I think the sooner the better), by which the interest of the two shall be so bound together

that the interest of one shall be *equally* the interest of the other. A system of industrial partnership appears to me to be the solution of the problem. In this partnership capital should have some fixed minimum rate of interest, and the workman a fixed minimum rate of wages, the profits resulting, after these have been met, being divided equally (or in some other proportion) between the two. This scheme might answer if profits were always certain. Of course profits *ought* to be certain, and the absence of profits merely the result of accident. This difficulty would be met by not dividing all the profits when made, but keeping in hand some proportion to build up a reserve fund, from which the minimum interest on capital would be made a certainty in the time of the lean years. The workman's wages having been paid weekly, he would have nothing to receive at the end of the term, unless profits had been made, and I am inclined to believe that the incentive given by this method would be such as to ensure the desired result.

The idea may be deemed Utopian, and it may also be contended that it has been tried and has failed, and to the latter contention I am quite prepared to assent. I am also prepared to assert that in every age there has undoubtedly been someone who lived before his time, and further, that many failures do not necessarily prove a scheme to be unsound or impracticable. Failures may only prove that the conditions were not suitable, or that some leading factor has been omitted from the calculation. The industrial partnerships of the past have failed in most cases in consequence of the trade union factor being ignored, or not having been sufficiently allowed for. In many of the cases the scheme was inaugurated to get rid of the trades union factor, which in the long run proved too strong to be thus dealt with. The wisdom or folly of any such scheme cannot be tested by isolated cases, and the success or failure

of any previous experiment cannot be taken as determining the ultimate result. The tendency of the times in several directions is, in my opinion, to bring this subject within the range of practical politics, and I am inclined to think that there are those present in this room who will live to see the idea put into practice in a more or less complete form.

Before I leave this subject I will mention what, to many of you will be common knowledge, that, at any rate the rudiments of such a scheme is in operation in the manufactured iron and steel trades. The Cleveland district is more particularly the one I have in mind, but this, I believe, also prevails in the other iron and steel centres. It is well known that the makers' books are examined quarter by quarter to ascertain the selling price of each commodity, and from the prices so obtained an average is struck which regulates the prices to be paid to labour for the ensuing quarter. In this manner labour participates in the prosperity, and shares in the adversity of this branch of industry. I am not sufficiently acquainted with the inner workings of this arrangement to pronounce any judgment upon it, but it certainly appears to me to have the elements of a working scheme which can be applied to much more complicated businesses than that of the manufacture of iron and steel. The weakness of the arrangement, to my mind, is that it does not make the workman a participator in the profits, but only in the market price of the material, therefore it loses the inducement on the part of the workman to reduce the cost of production. It certainly has done *this* amount of good, that whilst before the scheme was inaugurated strikes were of frequent occurence, now they are practically a thing of the past, and, as a consequence, both capital and labour have reaped an immense advantage from the arrangement.

So far, gentlemen, I have dealt with the matter on somewhat general lines. I now desire to draw your attention to what is

taking place at the present time. As you are all aware, there have been orders placed in America within the past few months for a number of locomotives, some of which have been delivered and some are now in course of delivery. We are all aware that the reason ascribed for these orders being placed in America was, that it was impossible to obtain deliveries within anything like reasonable time from home manufacturers. I suppose we must accept this as true, but, I ask, is it creditable to us as a wide-awake business people that we have not sufficient energy, forethought, and adaptability to increase our facilities to keep pace with our requirements. The fact that America can supply her own wants, together with a large foreign trade, including our colonies, and still have left a sufficient surplus of producing power to supply a portion of our wants, proves the case against us. I think no one will be bold enough to assert that there is not sufficient capital in England to extend and increase the number of works for the manufacture of this particular branch of engineering. If there is the capital, is there the energy and enterprise to use it? I know that this question may be met by the answer, that it would be all very well if this present activity could be guaranteed to continue. What are we to do about the locked-up capital in the years of depression in trade? My answer to this argument is that exactly the same laws of fluctuation prevail in America, and yet it does not prevent the Americans from rising to the demands made upon them.

It may be said that at home many of the Railway Companies manufacture their own engines, and therefore there is not sufficient scope to warrant private enterprise in fixing capital in this particular branch of business. I am by no means prepared to accept this as a sufficient answer. I believe that with greater energy on the part of private enterprise, the market for supplying locomotives to our own railways would have been a much larger one than it is at the present time, and that the Railway

Companies were in a large measure compelled to make themselves into producers, in consequence of the lack of facilities for obtaining their locomotives, etc., from those whose legitimate business it is to supply them. Private enterprise should and I feel sure can produce and sell with a reasonable profit, at a less price than Railway Companies can build their own engines. Sentiment may have had some influence, but I think Railway Companies are managed on lines with which sentiment has little consideration, and that given equal facilities and advantages they would quite as soon purchase engines as make them. Even should exception be taken to this latter proposition, I do not see that this materially alters the original proposition, as many of the American Railway Companies also build their own engines, and I have no doubt that they are also compelled to obtain engines from outside sources to meet their immediate and pressing requirements, but we never hear of them coming to England for engines at their time of special demand.

There is another branch of engineering which has been and now is suffering from an invasion of the American. I refer to the building of stationary engines for electrical installations, both for lighting and traction. Is it because the Americans can build a better or more suitable engine for the purpose, or can they supply an equally good engine at a lower price? I am aware that some orders were placed there during the strike period, but there are cases where orders have been placed in America since that time, and which I am sure could and should have been executed in this country. We all remember what has taken place very recently at Glasgow, that out of a requirement for four large engines for tramway traction purposes, the order for two of these engines has been placed in this country and the order for two has gone to America. Could not the construction of the four engines have been undertaken by English firms, and if not, why not? Each may answer this

question in his own way, but to my mind this placing even part of the order in America points to a lack of energy and enterprise on our part, and clearly proves that we have not placed ourselves in a position to deal with this or any other work of a like character of whatever magnitude. I am afraid we have got into a much too easy-going, self-satisfied style that we have become too well off, and like Jeshurun of old we have waxed fat. It appears to me to be a very humiliating position for us as engineers, that the foregoing orders for something like 100 locomotives and for at least 25 sets of large stationary engines, (one firm alone having supplied this number in the last three years) should, from any cause whatever, be placed outside our own land with all its boasted skill and constructive power. These orders will in the aggregate amount to about half a million of money, and I see no sufficient excuse for them being executed abroad, except our apathy, want of energy and inadaptability,

The foregoing does not even exhaust our delinquencies on this head. Russia at one time was our best customer for steam engines (stationary and locomotive), but now the orders for this class of work are few and far between, as far as we are concerned. What is the explanation? Do they manufacture these for themselves now? Yes, to some extent, but by far the largest number of orders for the stationary engines required in Russia go to one firm in Switzerland. I say all honour and credit are due to the firm to which these orders go, for their enterprise, or whatever other cause may have led to this result. From what I can learn this firm not only secures the orders, but they secure them at better prices than English firms quote, when they have the opportunity of quoting. The specimens of engine work supplied by this firm, which I have had the opportunity of examining, leaves nothing to be desired on the score of quality, but surely engineering firms in England can do as good work and obtain as good results as any engineering firms

the world through. Then why have we let this market slip through our fingers? I can give no other reason than what I have before given, viz.: apathy, lack of energy, and inadaptability.

Our machine tool makers will have to be up and doing if they wish to hold the excellent position they have hitherto occupied. Within the last few years there has been a movement in the right direction by those who are responsible for this class of work, and the automatic labour saving tools, which are so much in evidence on the other side of the Atlantic, are being manufactured here in constantly increasing numbers, and greater care and thought are being given to the production of tools, which will enable work to be produced cheaper and better than formerly. From what I have seen of American tools for doing heavy and medium-sized work, I do think that our machine tool makers are far ahead of our competitors, and, providing they will only be content to keep awake, they have not much to fear.

There will always be some men who *must* travel on different lines from the ordinary run of mankind, and who, from fear of being thought antiquated, will purchase the latest novelty, without in my opinion giving sufficient consideration to its economical advantages. I am glad that there are such men, and it may be that they are only living a little before their time. They certainly answer the useful purpose of acting as a spur to the slower and perhaps soberer portion of mankind,

A few months ago I had the opportunity of inspecting some American lathes, which, as specimens of workmanship, were very good; as specimens of suitability for the work they were expected to do, they were in my opinion very bad. They had a goodly number of appliances never seen on an English built lathe, and which will, I believe, be either taken off in a few months, or perhaps left on but never used. The non use of

these appliances will probably be set down to the stupidity or obstinacy of the workman. In these particular machines I am quite certain that if a fair and honest trial could be made between them and English made lathes of the same rated sizes, both better and more work would be done on the English machines, and yet these lathes cost quite 50% more than equal sized machines of English make, by first-class firms.

There is one branch of engineering in which up to the present competition has not invaded our shores. I allude to shipbuilding and marine engine building; but even in this particular branch of engineering our two competitors (America and Germany) are now in a position to supply almost without exception their own requirements, and are, especially the latter, supplying some other countries with a large portion of their needs in this line. I ascribe this more particularly to political influences than to those of an economical character. Our supremacy, even in this, which we may term our national branch of engineering, is being successfully assailed, and we shall have to take greater heed to our steps than we have done lately if we are to maintain our supremacy. We have allowed Germany to make herself possessor of the blue ribbon in the races across the Atlantic; we also allowed her to hold for a time the honour of having built the largest steamer the world had yet seen, and I do not think it will be long before she again takes that position.

In the manufacture of textile machinery I believe we are, up to the present, unassailable. In the attempts that other countries have made, to dispense with our services in this particular branch of engineering, their work comes immeasurably behind ours, and it is only through political jealousy and national prejudice that our competitors in this branch of business exist at all.

There are other businesses of an engineering character which might be dealt with, but I have touched on sufficient to create,

I hope, some interest in your minds on a subject of such vital importance to the welfare of this country in general, and of engineers in particular. The subject is one that demands the most careful consideration of every one, not engineers alone, but every one who may have the welfare of this country at heart, and unless we are prepared to take prompt and, I fear, drastic measures, we shall have to bewail a still further falling away from our position as a foremost producer.

When the present abnormal demand is over and the world settles down to a scramble for work, then will come the testing time, the competition will not be confined amongst ourselves, and, unless we take steps to place ourselves in a better position to meet the outsider, I am afraid we shall in the end come off very badly.

In the foregoing I have dealt with our position as engineers as I see it, others may view it from different points, and may attach much less significance and weight to the position than I do, but I venture to think that the more consideration they give to the matter, the more weight will they be inclined to attach to what I believe to be an extremely grave question. At any rate, in thinking over the subject in the course of preparing this address, it has impressed itself upon my mind, as second only in gravity to the war upon which we are at present engaged, and it will probably be even more far reaching in its results, unless vigorous steps are taken to amend our system of working.

VOTE OF THANKS.

Mr. Thomas Ashbury said the address bristled with points of interest, and affected everyone present. The practicality of the address would commend itself to all of them. They, as

Englishmen, would feel the spur that had been given to them, and no doubt it would prove very effectual in bringing about a better state of things. They all wished to see the supremacy of their country maintained. The Manchester engineering industry represented an important part of the world's production, so far as machinery was concerned, and if they were to hold the prominent position indicated in the paper they would have to leave those things that were behind and press forward, and show that adaptability which had been referred to in the paper. They must make and sell those things which the world required, at such a price and of such a quality that they would be able to defy competition from any country. They were not dead yet, and were able to face the competition. They must be wise and, while things were pleasant and the sun was shining, provide for that day which would certainly come when they would have to meet the blast, so that they would be able to stand vigorously against it without flinching. He had pleasure in proposing that the best thanks of the members be given to their President for his practical address.

Mr. Joseph Nasmith, in seconding the motion, said the President had referred to piecework tending to improve production. It might do in some cases, but his own experience during the last two years, in connection with the industry with which he was more particularly connected, was that while they paid men good piecework prices, so that they could make for a very small job £2. 5s. per week, the workmen took care, on the one hand, that no man should make more than £2. 5s. per week, and, on the other, the worst man in the shop should be able to earn that amount, so that there was not much advantage. If, however, they were to put the men down to 34/- they would only get 34/- worth of work instead of £2. 5s. That was one of the things they had to fight against.

When in Brown & Sharpe's works he noticed in the universal screw-making machine department that most of the men were minding two machines, some as many as four. Amongst the operatives there were men of all nationalities, including even an Armenian. They must not forget that in America there was always a large number of men going into the country to whom a dollar and a quarter a day seemed big wages, and employers there always had at their hands any number of men willing to be brought in and taught to be efficient workmen, so far as minding machines was concerned. Now, in England there was not that surplus population always pouring in that they could utilise, even if they were allowed.

They were always getting consular reports with the never-ending complaint that English goods were being displaced by goods from Germany, America, and other countries, simply because Englishmen would not study the needs of customers. He thought that sort of thing had gone far enough. They did not find the astute Yankee telling people that others could make a better thing than he could. He ascribed a great deal of the loss of trade to our national habit of self-depreciation, and he thought it was one of the things against which we should guard. They should make a study of everything that was being done abroad. It would not be a bad thing, and it was in contemplation in Manchester, to have some examples of the latest and best things that were being made in the engineering world, in order that they might study them and, if there were any improvements, adopt them.

When he visited America recently he went across with a gentleman engaged in bridge building, who told him he was one of the tenderers for the Atbara Bridge. He (the speaker) came back again with the same gentleman, who had in the meantime gone over all the bridge works in the United States, including the famous Pencoid Works, from which this bridge came.

This gentleman said he had had the order for the bridge, and undertaken to deliver it in twelve week's time, this point of time being one of the greatest importance. One of the authorities in Egypt, however, had been in communication with the Pencoid Works, and actually got the tenders over the heads of the people in London, and ordered the bridge by cable without telling the London people anything about it. Then again the English engineers on this side of the Atlantic who were interested in bridge work always had the holes drilled, the plates planed on the edges, and the bridges fully erected in the yard, and everything marked in position before it came down. That was not the practice in America. They simply made the bridges to templates; they did not drill any holes; they punched every hole, took all the web-plates exactly as they came from the mill without any planing, and they would sometimes see a joint open ⅜in. instead of being butt to butt, and that was the type of bridge which was taken across to Egypt. Could they wonder that in view of the different conditions under which the tenderers from England and America quoted for work, English engineers did not always get the orders. To his mind it was little short of a scandal that an English consulting engineer should say to the Englishman "You shall do this and that," but when he came to deal with the American engineer would take what the latter gave him without insisting on the conditions stipulated in the case of the English firms. They did not grumble at competition, but let it be fair competition.

As to sending locomotives to America, how could we do this when there was a 40% duty, whilst we allowed theirs to come in free? If the conditions were equalised, and the Americans would not "skulk behind the trenches" of protection but would come into the open, we could have a smack at them.

The President had dealt with questions at which he himself had been hammering away for a long time. We must have

more alertness of mind, and the only way in which this can be got is by making up our minds that those who were to take up any branch of manufacturing should be thoroughly educated and fitted for the work they have to do. They, as an association, and every engineer who had any voice at all in the town he came from, should see to it that such a system of education was established, and such opportunities in the way of scholarships given to even the poorest, that we should be able to train a set of men in the future who would be equal to the most highly trained products either of Germany, with its theoretical pedantry, or America, with its practical bent. In the last-named country considerable thought had been given to the proper training of technical students, and the result was seen in the fact that men were now being turned out who combined with knowledge obtained in admirably equipped schools, practical knowledge obtained by actual work, and, joined to that, all the Anglo-Saxon ability in mechanics, which was very highly developed in the nervous air of the States.

Mr. John Craven said the address to which they had listened gave practical suggestions which they should take to heart. The President had dealt with the subject with a boldness which few men dare approach. He had told them something of the abilities of English engineers, and also of their faults, and had certainly said something which ought to be of very practical advantage to them all. They need not fear American competition or German competition, but they must bear in mind that in England they generally laboured under the disadvantage of having workshops far too small. If they went to Germany or America they would find there were acres and acres of land on which a shop when once planted immediately commenced to extend as requirements necessitated. In England we had no shops in positions of that kind, planted in the middle of a great

field, in which they could cover acre after acre when they wanted to increase their production. Generally our workshops were small ones, and there were no means of extension. It was, consequently, only one or two enterprising firms that could increase their production by means of adding to their workshops. With regard to steam engines, it was certainly true that the firm the President referred to was taking a very prominent position with regard to supplying large stationary engines in Europe. We had not such a firm in this country, from the fact, he thought, that we had not room enough for individual firms to extend their works in the way that the large continental firms did.

There seemed to be no want of capital either in America or on the Continent for industrial enterprise, and we ought not to be short of it. He thought, however, English engineers had been rather too modest in asking for it. There was really abundance of capital, and people were contented with even a small rate of interest.

He thought that engineers, instead of putting workshops in the middle of small Lancashire towns, or in the immediate neighbourhood of Manchester, should get to places where there were thirty to forty acres of ground at a cheap rate, so that when prosperous times came they could add shop to shop, and take any work offering. They could then do the work quite as well as their competitors.

The President, in responding to the vote of thanks, said his object had been to impress upon them the necessity of being "up and doing." They had too long kept their hands in their pockets, and the sooner they pulled them out the better. He did not fear foreign competition if they had fair play. He thought we could do as good work as the Germans, the Americans, or any one else. We had the brains and the money,

but it was of no use locking the money up; it must be put in use. Engineers had, as Mr. Craven had said, been too modest in asking for money. They required to enlarge their shops, there was no mistake about that. A shop employing 300, 400, or 500 people was not big enough to meet present requirements. The tendency all round was towards enlargement. Steamships were now very much larger than they used to be. Mills had also grown very much in size. An engine of 250 or 300 HP was reckoned a big job when he was an apprentice, but this was no longer the case; engines had to be at least 1,000 HP before they began to be talked about. The requirements of electric traction meant 10,000 HP in one unit, and before very long they would have to be prepared to make engines of the requisite power, or stand aside and let the Americans make them. They could depend upon it that the latter would build shops, and make and buy tools and appliances that would deal with such work.

HEALTH IN THE WORKSHOP.

READ SATURDAY, 24TH FEBRUARY, 1900.

BY

Mr. J. D. SUTCLIFFE,

(MANCHESTER).

The scope of this paper seems almost too wide, for it might embrace anything from the drains under the basement floor to the ventilators on the factory roof. I shall, however, be content to place before you a few practical hints gained in the past 18 years. During this time I have inspected and advised upon workshops and factories in all parts of Europe. Much has already been accomplished, but a great deal remains to be done if there is really to be "Health in the Workshop."

In the final report of the "Dangerous Trades' Committee," recently issued by the Home Office, you will find a record of "Death in the Workshop" which is simply appalling, and later on you will see some illustrations and hear some extracts from this report.

A tidy, clean and healthy workshop is a better investment than a balance at the bank. The owner who says he cannot afford to spend money in keeping his workshop bright and tidy is in much the same position as the workman who says he hasn't time to sharpen his tools. With a dirty, ill-ventilated and uncomfortable workshop, as with a blunt tool, the work is sure to be slipshod and the average low.

Too many firms are content to plod along in the unsuitable workshops that were in use 50 or more years ago. They were good enough for their fathers and they are good enough for

them. They cannot do much for their ancesters now, but much can be done for their workpeople by stepping out of the old groove.

One of the most encouraging signs of the present day is the strong desire that has grown up to be what is called "physically fit." Many clerks have left their employment to find work at out-door pursuits, and from the highest to the lowest there is a desire for chest measurement and physical strength. Doctors have largely fostered this spirit, and tell us that tuberculosis or consumption is largely due to the lack of fresh air. In time failure to reach a certain standard of physical fitness will probably be regarded as a disgrace.

A few years ago almost every working man had a wish to see his sons grow up to be clerks, so that they could wear a collar and a black coat every day instead of only on holidays. Now labour with the hand is gradually gaining ground at the expense of so called labour with the head, and it leads one to hope that the workman growing up will be a better man than his father, both physically and mentally.

We have to-day workmen who cannot be excelled in the whole world when their energy and skill is properly directed. As an instance of this, mention may be made of the recently completed "Rylands" Library. There you will find stonework, woodwork, iron and bronze work carried out with consummate skill that has probably never been surpassed in this or any other country.

The curse of the last decade was the demand for cheap goods and all efforts of the manufacturer have been to cheapen, cheapen, cheapen, Now there is a genuine demand for the best that human skill can give us, and this will go on increasing until cheapness has to take a back seat whilst skill and honest work will find its own place in the very front rank.

Legislation for the Young Workers.

To help along this good time is the duty and privilege of every one, and the state has certainly been assisting, especially in recent years, to place women and children under healthier conditions. In the early history of labour legislation, the state did not concern itself with the physical condition and intellectual well-being of young persons, but now with all political parties there is a steady adherence to the policy of exercising vigilant oversight over their welfare.

In America, Austria, Switzerland and other countries, children do not commence work until they are 14 years of age, whilst in a few continental countries they are not allowed to work until they are 16. Military considerations, no doubt, largely influence these nations, as they wish to raise for their armies strong men, and to do so they must protect and educate the children.

The attempt is always made to show how great a hardship it would be if some of the families of the poor were deprived of the income which they derive from the labour of their children. If this slight addition to the slender income of the family is to be weighed against the welfare of the children themselves, then the standard is wrong and ought to be changed.

When boys and girls can leave decently conducted homes and schools where they have not been crammed with useless facts, but where eye and hand have been trained to be useful and exact, then there will be some pleasure in being an Employer of labour. Our duty has not been done to the children, and this is one of the reasons why the Germans, Americans and Canadians have run us so closely in certain manufacturing pursuits.

Canadian Employer's Comparisons.

In Canada and America much more attention is paid to the cleanliness and healthfulness of the factory than is the case

with us, and one reason, at all events, for this is that the workpeople are better educated, and demand better conditions as a right. How far this helps them to compete with us cannot be said, but a few years ago a Scotch Canadian, whose works were outside Toronto, was exhibiting axe heads and scythe blades at our Royal Show, and his opinion may be worth recording. Asked how he managed to compete with the Sheffield makers, he replied "because I have better works, better tools and better men." He went on further to say that his workpeople came to the factory in good clean clothes, and even in white shirts. These were changed in well warmed cloak rooms and lavatories, and when the day's work was done "they washed and dressed, and went home like gentlemen." He pointed out that the English workman in the same trade would probably wear a pair of clogs, and a scarf round his neck, and be afraid he would catch cold if he washed himself before he turned out in the morning, and that he had generally a "come day, go day, God send Sunday" expression about him that was anything but conducive to good and rapid work. He further said "I buy most of my steel in Sheffield, I pay freight (and a small duty) to Canada; I pay 20% to 25% higher wages than in England, and yet I ship the bulk of my manufactures back to England and sell quantities of it in Sheffield." How much of this Canadian's success was due to the factory, the tools, or the workmen is difficult to estimate, but all are agreed that a healthy factory, with workers who are physically strong, is better than a dirty factory with slow anæmic workers who cannot possibly get through a good average day's work, and it is my desire to now place before you some practical hints of how the workshop is to be maintained in a healthy condition.

The Effect of Cold Weather on Production.

One of the first considerations is that of sufficient and efficient warming and ventilation, and this is not such a simple

subject as some folks seem to imagine. A large employer of labour in Wolverhampton said that his production went down as much as 20% in extremely cold weather, and he attributed it to the fact that many of his hands would not come to work before breakfast, and that those that came found the place so cold that they couldn't do anything but look after their breakfasts until breakfast time.

There is no formula to be given for either the satisfactory warming or ventilating of a factory, but examples from practice will be placed before you which will be useful, and if carried out will add to the general health and comfort.

The Cost of Good Ventilation and Warming.

The principal difficulty in the way of getting good ventilation and warming is the cost. In America it is no uncommon circumstance to pay 20% to 25% of the total cost of a building for adequate warmth and fresh air. How different this is to the English architect who frequently allows the generous sum of £5. in his estimate for a so called "Ventilating Cowl" to be fixed by the builder on the roof, and this has been known where the building cost over £5,000. There is also the factory owner some of us know, who when he is told that the ventilation of a particular room will cost £30, says "Oh, let 'em roast. I'll never spend £30. on ventilation!" Once this was said after the manager had told the proprietor that two or three girls were carried out of the room every day in a fainting condition. Such employers are becoming rarer, and we are now recognising that it is as necessary for the workpeople to follow their employment under healthy conditions as it is for them to have good food if the best results are to be obtained from their labour.

It is as well to recognise the fact that good ventilation and sufficient warmth cannot be provided for nothing, but in the long run they will actually pay better than many other things considered essential in all well designed workshops.

Perfect ventilation may be said to be secured when every person takes in at each breath air as pure as that outside the building. This is nearly impossible, but good ordinary ventilation is secured when the vitiated air is constantly diluted to a certain standard.

In the Cotton Cloth Factories Act the standard is nine parts of carbonic acid gas (CO_2) in 10,000 parts of air.

Country air contains on the average four parts of CO_2 in 10,000 parts of air, but probably in some streets and alleys in Manchester the outside air contains as much as seven parts.

Pure carbonic acid gas is by no means injurious. Mineral water factories and breweries frequently have 50 to 150 parts in 10,000.

How to Test for Carbonic Acid Gas.

You may therefore ask, why this fuss about CO_2 if it is so little harmful? Well, the reason is that it is nearly always found in bad company, and that variations of three or four parts indicate the presence of other gases, vapours and impurities which are really dangerous, and also because it is easy to test air for CO_2 but it is not easy or reliable to test air for the other dangerous impurities.

An apparatus for testing the CO_2 in any room is shown in Fig. 1, and a sample of air shall be taken from this room and compared with the outside air, and at the close of the lecture you shall know the result.*

This apparatus was designed and arranged by Dr. Scurfield, the Medical Officer for Sunderland. It is portable, very quick in action and fairly reliable, and is frequently used for testing the air in weaving sheds, schools, &c.

Each of the tubes shown contains an equal amount of a weak solution of baryta—an alkali—coloured pink with the indicator phenol-phthaleine, and as the acid in the air acts on the baryta and neutralizes it, the pink colour gradually disappears.

* The test showed that the air in the lecture room contained 13·65 parts of CO_2 per 10,000 parts of air, or 4·65 parts more than would be allowed under the Cotton Cloth Factories Act.

In using the apparatus, one of the tubes is connected to the can filled with water, and by an arrangement of piping the water is drawn off, causing the air by which it is displaced to pass through the solution, the amount of air passed through being measured by the amount of water run off.

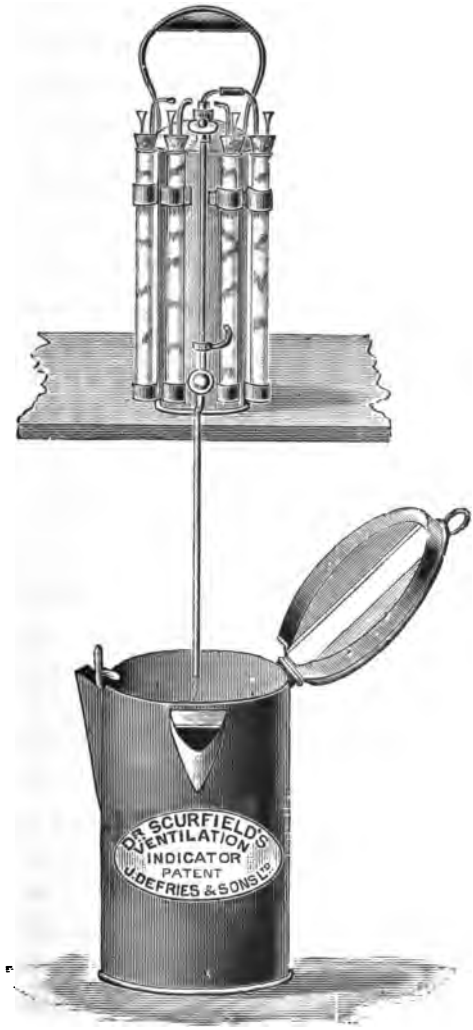


Fig. 1.

This is done inside the room tested and also outside in the free atmosphere, and it can readily be seen that if it requires only one-third as much air to decolourize the solution inside the room as outside, the air in the room must contain three times the impurity present in normal air. The Cotton Cloth Factories' Act says for the purpose of testing the air in weaving sheds, the free atmosphere surrounding the shed shall be taken at four parts of carbonic acid gas in 10,000 parts of air, so that in this case the air in the shed would contain twelve parts of CO_2 in 10,000, a proportion three above the allowance specified by the Act, but still, unfortunately, one often exceeded.

Cotton Cloth Factories and Schools compared.

It seems somewhat hard on cotton cloth factory owners to be compelled to keep the CO_2 down to nine parts in 10,000, when it is safe to say there is not a school in Manchester that would pass the same test two hours after lessons had commenced, and there are many schools where the CO_2 reaches 18 or 20 parts per 10,000 before the end of the afternoon.

The nose is usually an excellent guide to the presence of CO_2, as when anyone fresh from the outside enters a room a faint smell is perceived when the air contains seven parts, and if it reaches eight or nine we usually say the room is "close."

Cubic feet of fresh air required to maintain standard.

To dilute vitiated air so that it does not contain more than nine parts of CO_2 in 10,000, at least 2,000 cubic feet of air per hour must be supplied to every occupant in the room, and this air will have to be well distributed if the desired result is to be obtained. How to supply such an amount of air properly warmed and without perceptible draught is the problem that always faces the Engineer. There are men who believe it can be accomplished by "natural ventilation" and who think that to use mechanical means such as fans for either exhausting the foul air or blowing in the fresh air is a great mistake.

Natural Ventilation.

Let us examine the claims made on behalf of the so called "natural ventilation," where the air is extracted without the use of power other than the wind or differences in temperature. It is often supposed that by fixing a particular cowl, "syphon," "air pump," or other stupidly named patented article on the top of a building, currents of air will be produced by the cowl itself, and therefore if enough are provided the ventilation is sure to be all right. A greater mistake could not be made, and you frequently find that out of say six cowls fixed on a building, half of them will be admitting air and the other half allowing it to escape. The illustration (Fig. 2) shows a ventilator of this type. The inventor proudly tells you, as he calls your attention to the model, that if you blow across the ventilator it plainly "exhausts" as it lifts a piece of cotton wool from the bottom to the top. You have only to remove his ventilator and blow across the glass tube, when the cotton wool comes up just the same.

Fig. 2.

Automatic Ventilation.

Years ago the Sanitary Institute made some experiments with various "automatic" ventilators, and their report was to the effect that more air escaped through an open pipe of the same diameter than through any of the patent ventilators.

Mr. Allison, the late City Engineer, also made extensive experiments with "Archimedean" ventilators on the Mosley Street Art Gallery, and convinced himself that more air passed through these when stationary than when moving, and therefore he had them all pinned fast.

On factories and workshops the best outlet is the louvred wooden turret (Fig. 3). This does not obstruct the air in passing out and is a sufficient protection from the weather, but there is no exhausting power in it.

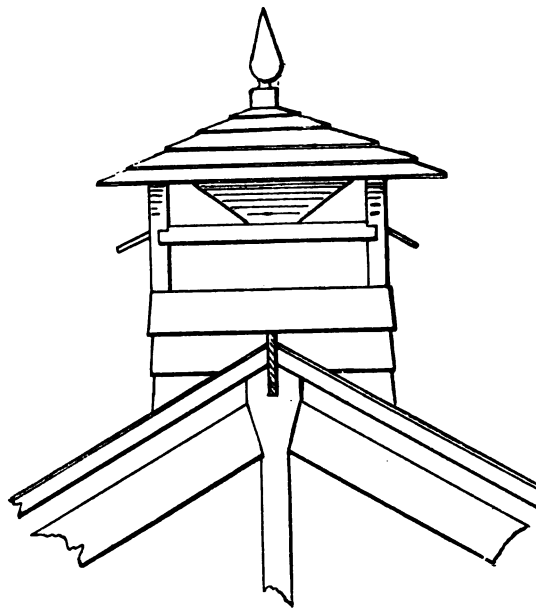


Fig. 3.

Mechanical Ventilation.

Many of the difficulties at once disappear if fans are used. The amount of air required is obtained simply by choosing the right size of fan and driving it at the proper speed, and then the only problem lies in the proper distribution of the air.

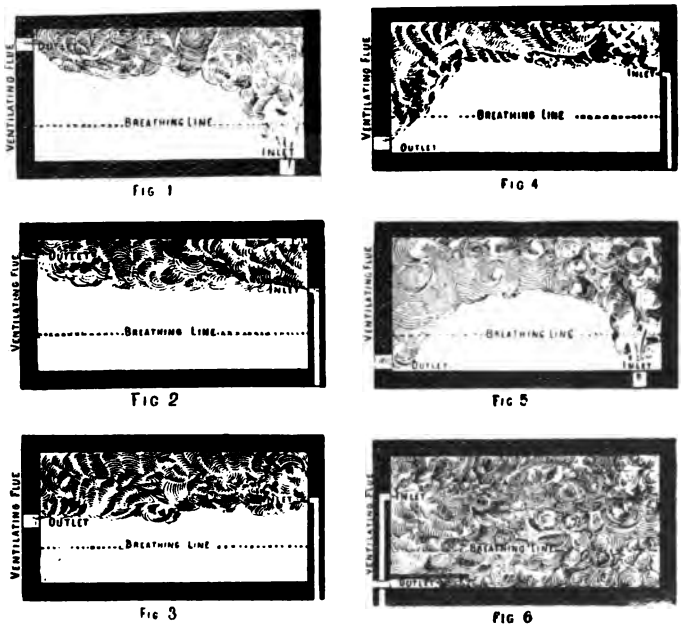


Fig. 4.

Air Currents and their Direction.

The next illustrations (Fig. 4) show the behaviour of currents of warm air under different conditions of inlet and outlet. They illustrate the result of some experiments made in America a few years ago to determine the course of air currents when admitted and extracted in several different positions. They were made by men who were honestly endeavouring to learn the method of introduction and exhaustion which would most thoroughly utilize the warmth and freshness of the air passing

through the room. A room was provided with glass sides and smoke and warm air were introduced at various points. The illustrations represent what was actually visible as the smoke and air passed through the room. The air currents would probably have been modified if the room had been occupied and the atmosphere disturbed by the motion and breathing of the occupants.

It seems at times a misfortune that air is not visible. We know at present comparatively little about its behaviour, but

Fig. 5.

if we could see it, many things which now puzzle us would no doubt be made clear. As illustrating this point a small toy (Fig. 5.) is worth attention. It consists of a tin tube about 6in. long and ¼in. diameter, with one end of the tube opened out funnel wise. If you were told that by blowing through this tube you could support a wooden ball an inch in diameter, and that the harder you blew the tighter the ball would hold, you would probably be disposed to discredit the statement. Yet it is a fact, and you shall have an opportunity of trying the toy later, when you may give your idea of how the air must behave for a "blast" to be turned suddenly into a "suction." There is another remarkable point to be noticed, for just beyond the ball a light may be blown out.

The position of Inlets and Outlets.

It has always been a debateable point as to the best position to place the inlets for fresh air and the outlets for vitiated air, and the question is often asked, should foul air be exhausted upwards or downwards?

Many authorities say it should be downwards for the following amongst many other reasons:—in the process of respiration fifteen cubic inches of carbonic acid gas (CO_2) is given off from the lungs of each person per minute. This gas is 52% heavier than air, and in its pure state can be poured from one vessel to another; therefore its tendency is to sink below the level of the mouth and occupy the lower portion of the room.

Those in favour of upward ventilation point out that air as it becomes vitiated almost always gets warmer than the surrounding air, and therefore has a tendency to rise, and in a decently ventilated room the diffusion of gases will be so complete that the proportion of CO_2 will not be sensibly greater at the floor than at ceiling level. This is proved by taking a small quantity of this gas and putting it into the bottom of a jar leaving ordinary atmospheric air above. The

jar may be closed, but in a short time the air will have worked downward and the CO_2 upward and the mixture will be the same throughout. It is also well to observe in this connection that you cannot separate them again unless you introduce some substance that will combine and absorb one gas and not the other.

It is usually safer to make outlets for vitiated air both at the ceiling and at the floor level. The top outlets should be fitted with valves to close at pleasure, or the warm air will pass out only affecting a very small portion of the room. With the bottom outlets only in use when warming the building, greater use will be of the heat as it will have to come down before it can escape.

The difficulty with air currents is in controlling their direction. For instance, if you admit air into a room, say on a side wall at 6ft. 6in. from the floor and direct it upwards to the ceiling, what happens? Well, that will depend on the temperature of the incoming air in relation to the air in the room, and will constantly alter as the temperature and velocity vary. If the air enters at considerably higher temperature than that in the room, the warmer air will go to the ceiling and probably diffuse itself there, travelling along to the opposite wall and then cooling and coming down or passing out at any opening that may be provided. If the admitted air should be colder than that in the room it will probably never reach the ceiling, and will certainly not cross the room unless a fan pulls it, and even then it may travel along the floor. Of course any intermediate stages of warmth will give intermediate stages of direction and velocity.

Double Duct System.

What is known as the "double duct system of combined warming and ventilating" is very satisfactory. It is used at the Salford Technical School, and the section Fig. 6 represents

the system as now being carried out at the Bury Art Gallery and Free Library.

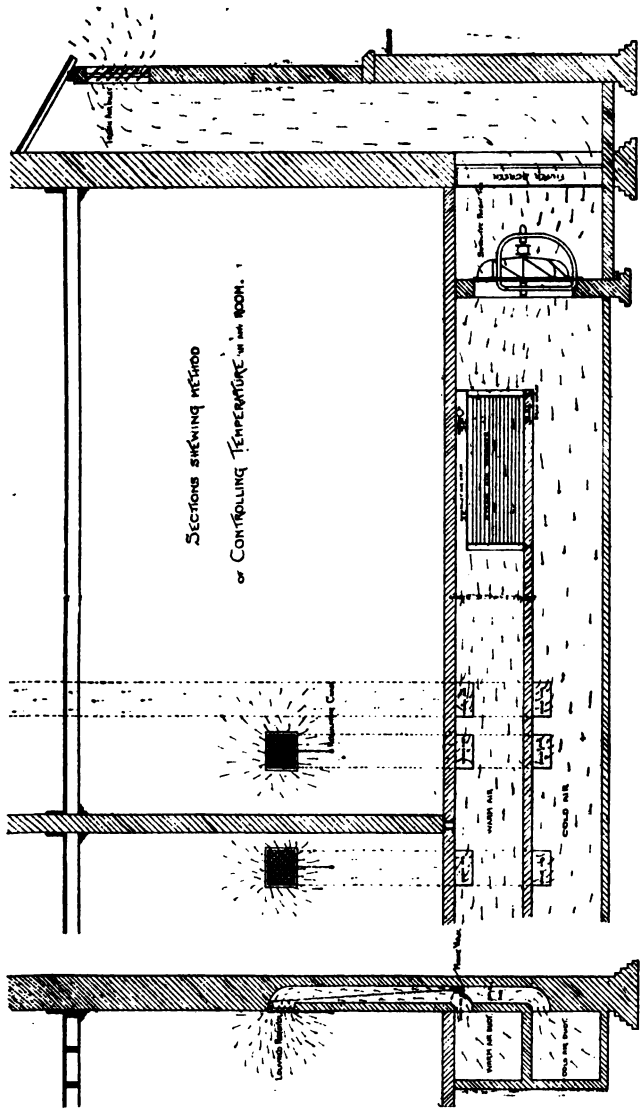


Fig. 6.

Controlling of Temperature.

In many buildings it is necessary to have different rooms at different temperatures. A room where heavy manual work was being done would of course require a much lower temperature than, say, a drawing office, and the illustration shows a method by which this can be easily accomplished. Each main air supply duct is made double, the passage for warm air being placed over that for cold air, and the branch ducts for each room are so arranged that they can draw their supply of air from either or both ducts at pleasure.

The drawing shows clearly how this is done. The fresh air is brought into the building from the outside, It passes through the filter screen to the fan, which forces it forward through the air warmer and warm air duct, or through the cold air duct according to the valves that are open. If the room is required very warm the regulating valve is dropped and all the air supply comes from the warm duct. If it is required to be cold, the valve is raised and the air enters the room at the normal temperature, or even lower in summer time. It will also be readily seen that the valve can be fixed in any intermediate position, and the air can be drawn equally from both ducts or mixed until the desired temperature is obtained. This system would be very useful in many factories, as the air could be conditioned to any required degree.

The Ventilation of W.C's.

It may be well to look at different rooms that require special attention, and the foremost and most important is the W.C's and other conveniences. The usual household plan of opening the window and blowing the foul air all over the house is not to be recommended. A better plan is to have an air inlet in the bottom rail of the door, or failing this have the door shortened so that there is a clear air space under the door for its full width and 1½in. deep. Then take the outlet through the

wall at the highest point and opposite the door. On the outside of the outlet have a protecting cover as shewn in Fig. 7. Of course, in a new building an outlet flue should be built in the wall and carried up to the roof.

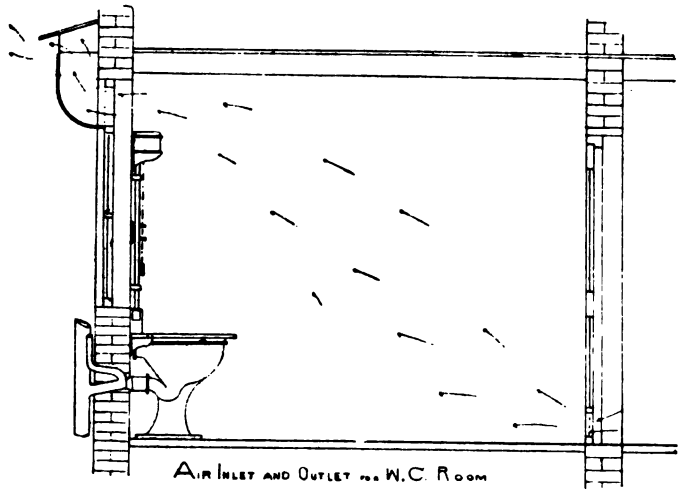


Fig. 7.

It is always a serious matter to fix a Fan exhausting from any room to which closets are directly connected, as the foul air from the closets is certain to be drawn into the room and this is more noticeable when the wind is blowing in at the closets. If there are a series one above the other, as Fig. 8 it is a good plan to fix an Exhaust Fan on the ceiling of the top closet, and connect all of them by means of a wooden tube. The foul air should be extracted at the level of the closet seat, and the fresh air admitted by cutting 3in. from the bottom of each door. The section, Fig. 8, shows the arrangement clearly, and you will see that by adopting this plan, you ventilate each room into the closet which is much better than ventilating the closets into the room.

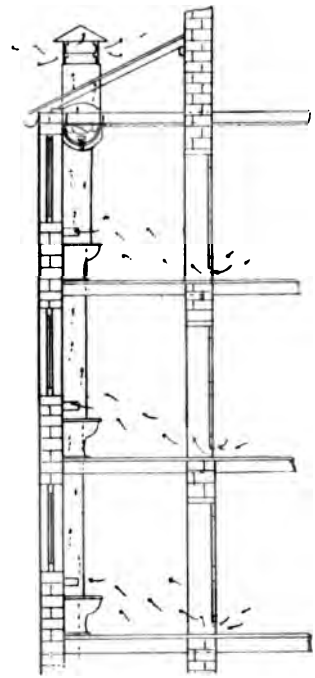


Fig. 8.

American Methods.

The Americans pay far more attention to the details of their factory W.C's than we do, and the next example, Fig. 8a, is a typical one. This consists simply of a slate vault with proper provision made for filling with water and emptying. There are no plumber's joints or traps and they are ventilated into a special ventilating flue which forms part of the chimney shaft. In winter there is heat enough in the smoke flue to induce a current in the ventilating flue, but in summer a special stove is used at the bottom of the ventilating shaft for the purpose of accelerating the draught. Standing upright over one of these closet seats the draught was strong enough to draw the smoke from a tobacco pipe down the seat.

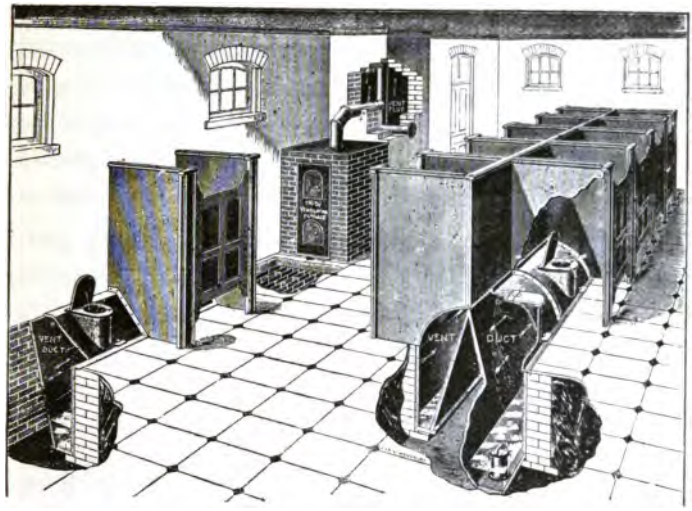


Fig. 8a

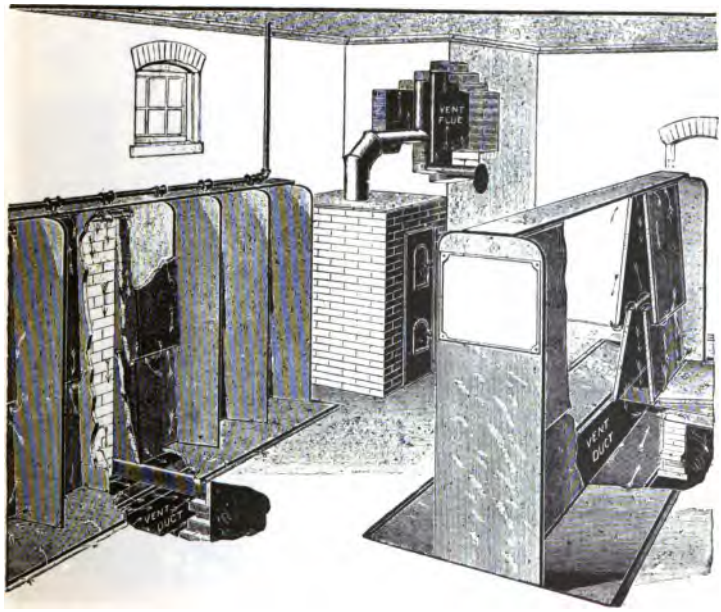


Fig. 9.

Fig. 9 shows a ventilated urinal on precisely the same lines. So long as the ventilating shaft is doing its work this arrangement will be odourless, as the air is drawn down to the floor level and into the ventilating shaft below. To ensure success on these lines it is absolutely essential to have a plentiful supply of fresh air admitted to the rooms where the closets are.

Before leaving this subject I should like to enter a protest against many of the sanitary conveniences for our Lancashire workshops and factories. Some of them are not fit for the use of human beings, and they must lower the self respect of any man who is compelled to use them.

The Removal of Dust.

In all occupations of a dusty nature the workers run the risk of lung affections, and especially is this the case with grinding and emery polishing, where the particles of dust are sharp and so penetrate and irritate the lungs.

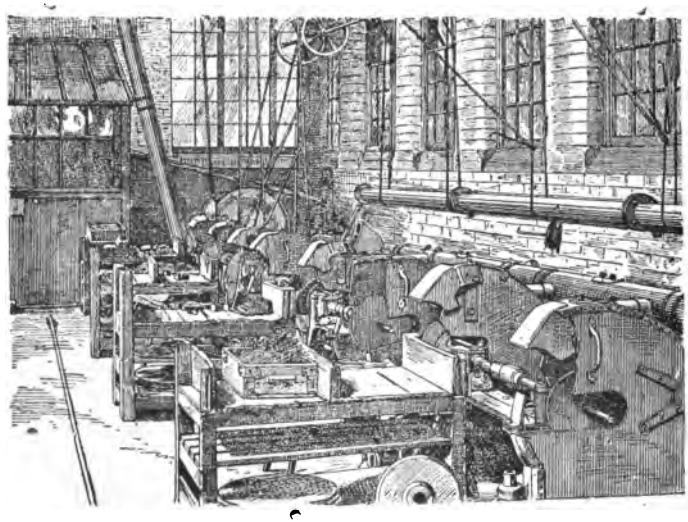


Fig. 10.

The illustration Fig. 10 shews an excellent method of dealing with emery wheels and other grindstones. The guard serves an important double purpose, as not only does it constitute a fence to protect the operative should the wheel burst, but it acts as a suction orifice through which the dust is drawn away by a fan.

This illustration and the next, Fig. 11, which deals with the actual building of millstones were made specially for the final report of the Dangerous Trades Committee previously mentioned.

Fig. 11.

Millstone building is one of the most unhealthy trades in England, and Dr. Peacock said of the men employed that 40% died of tuberculosis, and that "among 41 labourers, of whom 23 were not above 20 years old when they commenced the work, the average age reached was only 24·1 years."

Fig. 12 gives a simple example of dust being removed from polishing belts. These belts are largely used in some trades, and it is essential to partially box in the belt as shown and connect the covers to a fan if satisfactory results are to be obtained.

Some manufacturers object to the use of hoods or covers over their grind stones on the ground that they impede the work by restricting the action of the workman. This may be so in

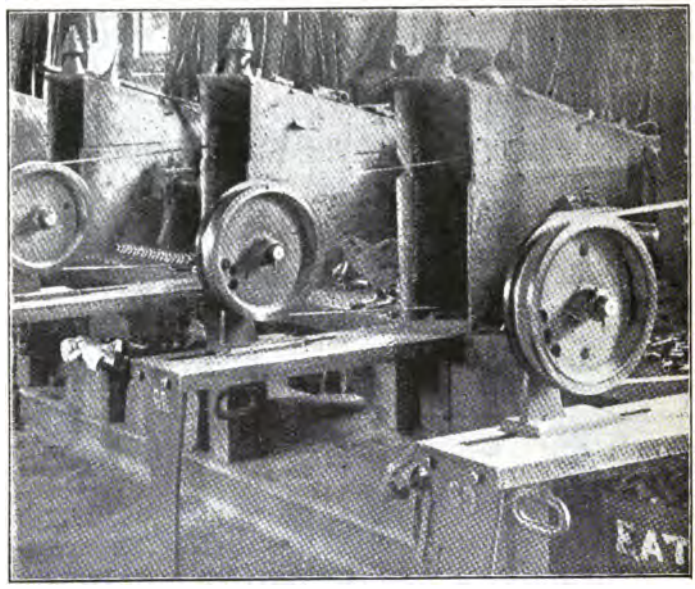
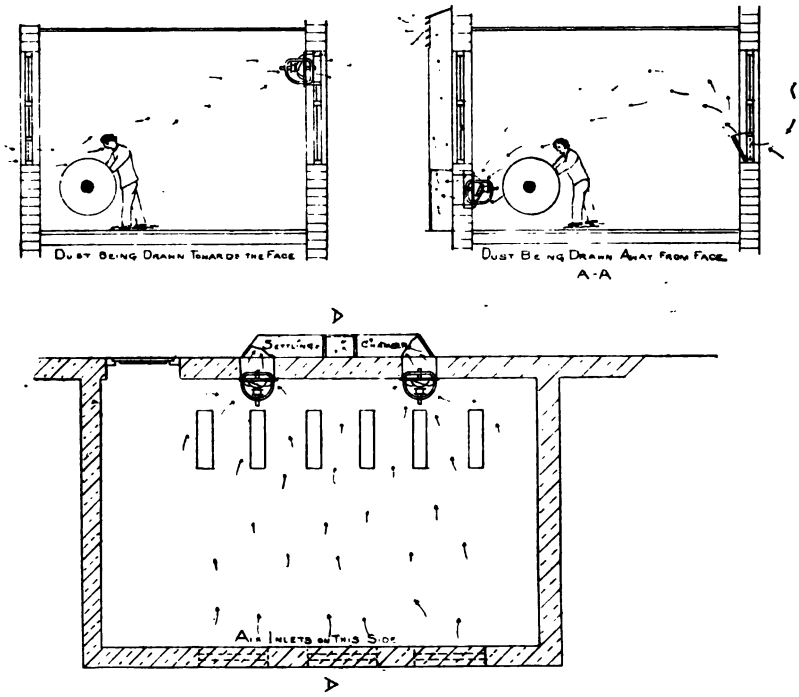


Fig. 12.

certain cases, but a hood should be provided if at all possible, as the action of a fan is more certain when its area is defined by a hood, and there is less danger to the eyesight from sparks and heavy dust.

If however, it is impossible to use a hood, then greater care will be necessary in selecting the best position for the fan, and the next illustration Fig. 13A shows "How a fan should not be fixed." You will see that the fan is fixed behind the man, and consequently any dust that may be drawn by the fan must pass over the man's face. This is entirely wrong as the fan should always be fixed in such a position that the particles of dust are

carried away from the face of the operative, and the principle is properly illustrated in Fig. 13B.



Figs. 13A. and 13B.

In this illustration a form of settling chamber is sbown, which is useful when the dust is valuable, or even when it would be a nuisance if allowed to blow about the premises. Many settling chambers are rendered useless by contracting the outlet which should always be equal to the area of the fan or fans.

Fig. 14 illustrates a method of dust removing from white lead packing, which has been largely adopted. The dry white lead is emptied by hand from small bowls into the casks, and the dust is drawn away at the back. A spray and tank of water

is provided on the discharge side of the fan, so as to catch as much dust as possible.

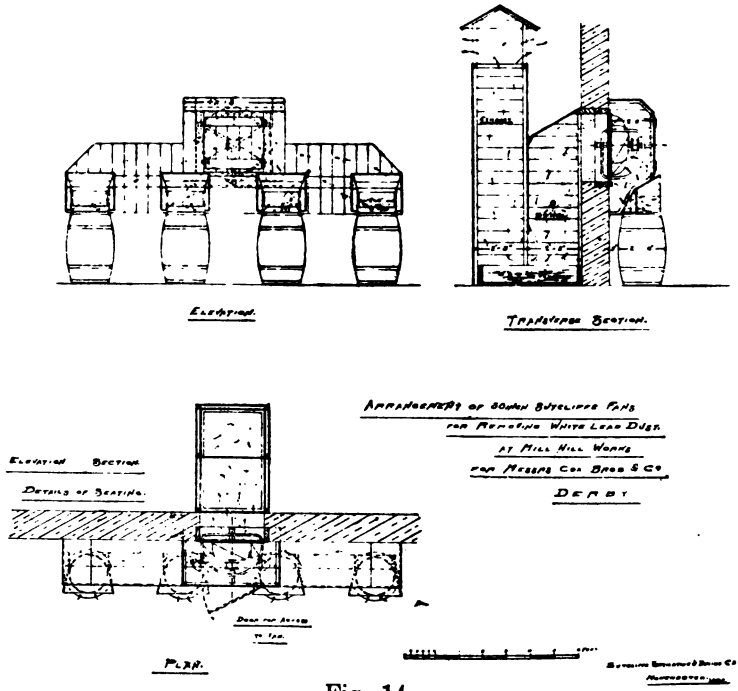


Fig. 14.

Pottery Workers.

The next illustration, Fig. 15, has especial interest because it was designed to remove the dust from the workers in the pottery trade, and hundreds of fans have been fitted on the lines shown. The girl cleans the ware or puts on the colour dust under the glass hood, and any floating dust is immediately carried away through the opening at the back of the hood and down through the bench to the fan. A velocity of air of 500 feet per minute is necessary to ensure the removal of all the dust.

Lead Poisoning.

Recent statistics prove that cases of lead poisoning or plumbism have been reduced since the passing of the special

Fig. 15.

rules, and there are very few potteries now where the rules are not carried out rigidly on the employer's side. It is not too much to say that if the workpeople only exercised reasonable care on their part plumbism would soon be a disease of the past, so far as the pottery trade is concerned. Unfortunately there are a minority of the workers who have had no training in personal cleanliness and seem to abhor the idea of it. A case in point happened some time ago. One of the largest pottery manufacturers in Staffordshire—a man who a few years ago was himself a workman—determined to do everything the new rules required, and more if possible, to keep

his workpeople in health. Fans were well and suitably fitted in every room, overalls were provided and washed at his expense, hot and cold water lavatories with good supply of soap, towels and nail brushes were always in readiness, and yet one of his female hands was amongst the first to suffer and die from lead poisoning. The fault was entirely her own, as it was proved beyond doubt that she had been in the habit of taking chocolates and other sweets, as well as bread and butter into the works surreptitiously, and eating them while her hands were covered with the lead dust. What can an employer do under such circumstances? Nothing, except ask the School Board to see that scholars are taught the importance of personal cleanliness, even if some useless subject is left untaught.

Cotton Mill Ventilation. Card Rooms.

As many of you are connected with cotton mills, it may be as well to give some idea of how to ventilate a card room, one of the dirtiest rooms in a cotton mill.

If the cards are down one side only it is a very simple job. The best arrangement is to fix small fans, say 24in. diameter, in every third window on the same side as the cards. The height from floor to bottom side of fan should be 7ft. 6in. to 8ft. 0in. The air should be admitted at the windows on the opposite side of the room to the fans, so that it travels over the preparing machinery and then forward over the cards to the fans. This is shewn clearly in the top plan of carding room Fig. 16. Of course an improvement on this plan would be to blow air in over the preparing machinery as shown in the the section, and if this were warmed by steam pipes when necessary so much the better.

When the cards are on both sides of the room, then fans extracting the air must also be placed on both sides, and air blown down the centre of the room by other fans. This is

shown in the lower plan on Fig. 16, and makes a capital installation.

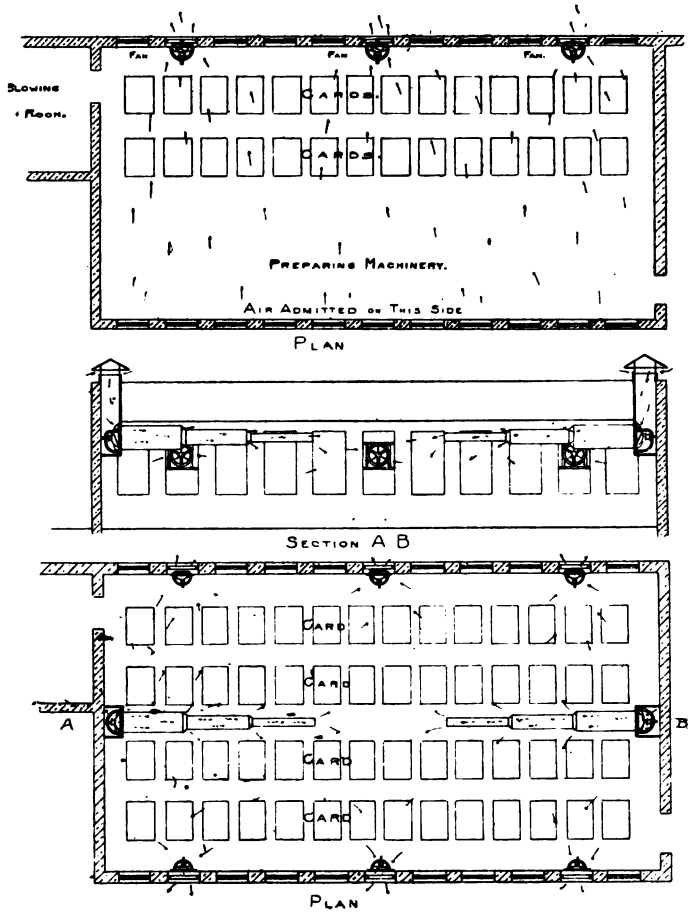


Fig. 16.

Ventilation of Weaving Sheds.

In the first Cotton Cloth Factory Act dealing with steaming in weaving sheds no test of the purity of the air was imposed, but each worker was to be provided with "not less than 600 cubic feet of fresh air per hour." This brought fans into general

use in all sheds where artificial humidity was introduced, and the improvement in the health of the workpeople was most marked. The usual method was to fix 14in. or 18in. fans, as Fig. 17, exhausting from the shed, and to provide fresh air inlets round the walls where possible.

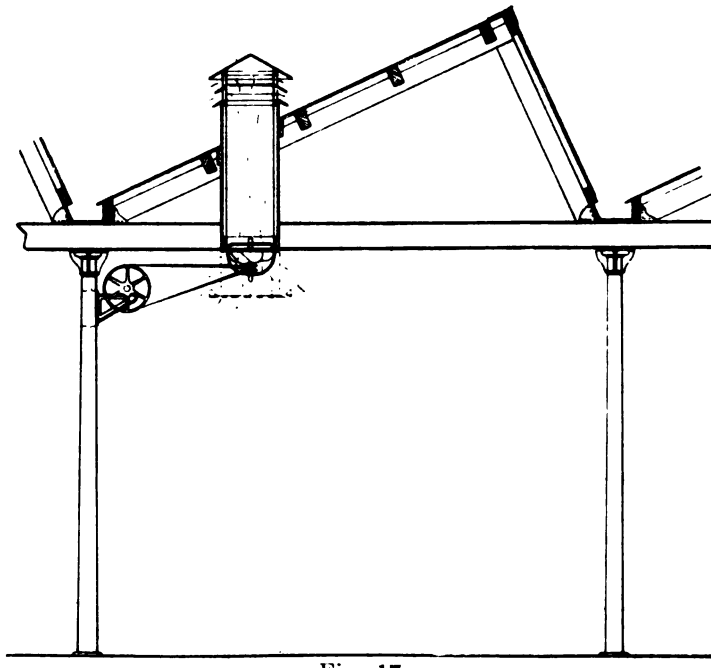


Fig. 17.

In the most recent Cotton Cloth Factories Act the standard of purity of the air is fixed, and, as stated previously at page 8, if this standard is to be maintained, at least 2,000 cubic feet of air per hour must be supplied for each worker. By experience it has been found that to fix fans for exhausting only is not sufficient, and it is necessary to fix fans "blowing in" as well if success is to be assured. Of course it is very different supplying 2,000 cubic feet each per hour, instead of only 600 as in the old Act.

If we take an example of a shed with 240 hands, there would be required (240 × 2,000) 480,000 feet of air per hour, or 8,000 per minute. A good type of 14in. Fan will supply a thousand cubic feet of air a minute, so that to effectually ventilate this shed eight 14in. fans should be used for exhausting the foul air out, and eight of the same size for forcing the fresh air in.

It will be found most satisfactory to run the fans blowing air in about 15 % faster than the exhausting fans, so that a pressure or plenum is maintained in the shed, and doors and crevices are made into outlets instead of draughty inlets, the case where exhausting fans predominate.

In the sketch plan of weaving shed, Fig. 18, the best positions for the necessary exhausting fans are marked with a small circle, and blowing-in fans with a X.

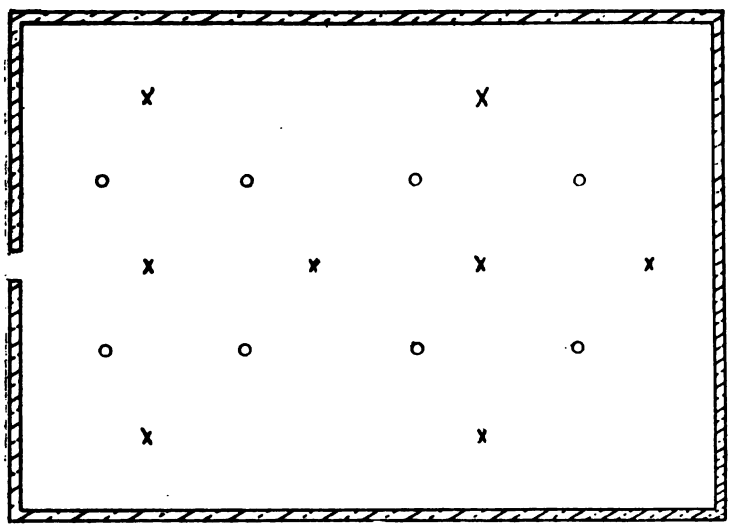


Fig. 18.

A few firms have obtained fair results by fixing the blowing-in fans in the same way as the exhaust fans, as previously shown in Fig. 17, but the fan is driven the wrong way round, so that

air is brought into the shed and discharged at the periphery of the fan. An air shield about 2ft. 6in. square, shewn in dotted lines, is fixed below the fan, to break the draught and distribute the air.

Another and better plan, since the fan is run the proper way and full duty is got out of it, is to fix the fan as Fig. 19 and turn the air down upon an air guard, effectually distributing it.

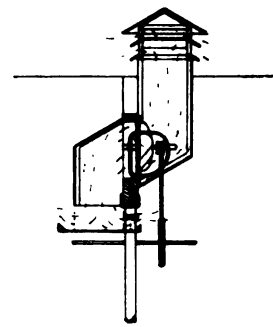


Fig. 19.

Steam Removing.

Many manufacturers who have no trouble with steam in their dyehouses and other rooms during the summer months are seriously inconvenienced directly the cold weather commences, and therefore it would appear that the condition to aim at is to have a summer atmosphere all through the year. The plan and section, Fig. 20, shews a practical example of how this desirable condition is to be obtained. The dyehouse shewn measures roughly 75ft. × 40ft., and on three sides is surrounded by other buildings. The roof has a louvred outlet running almost the whole length, and the steam was so dense during the winter months that it was impossible to see "your hand before you." To close up the louvres and fix a large fan, exhausting the steam, would only have intensified the trouble, as cold air would have been pulled into the warmer air of the dyehouse, and would have increased the condensation without removing

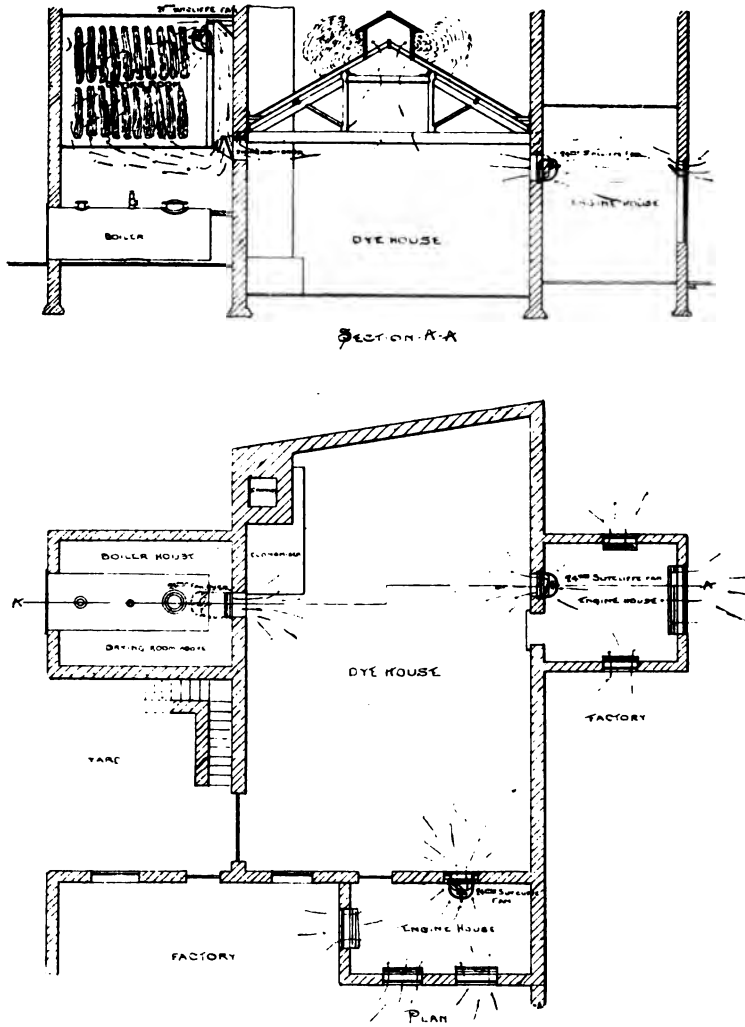


Fig. 20.

the steam. Instead of following such a plan, three 24in. fans were fixed in the positions shewn, and as they all obtained warm air to blow into the steam the results were extremely satisfactory. The warmth absorbed the steam, and now the

place is as clear in winter as in summer, and instead of a wet and dripping dyehouse dust may always be seen on the roof beams.

Noxious Fumes.

The removal of noxious gases and fumes should be dealt with in much the same way as dust, namely by hooding or confining

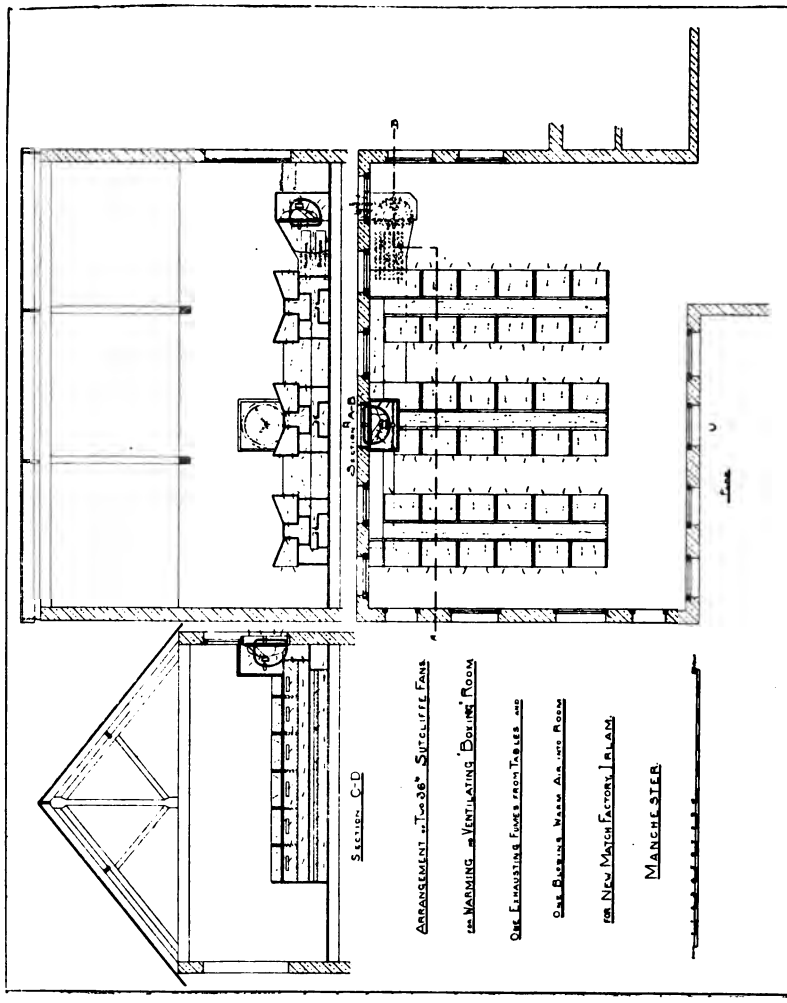


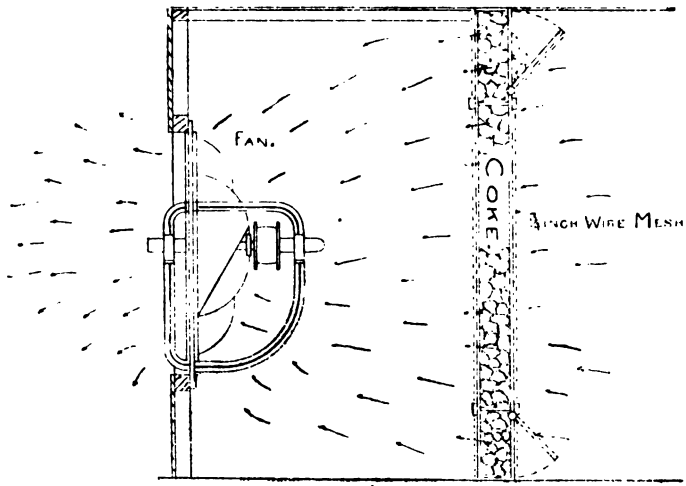
Fig. 21.

the sources of pollution and extracting the fumes away from the worker. This is very well shown in the illustration, Fig. 21, of the "boxing room" at the new match works at Irlam. The matches frequently fire during boxing, and a good deal of smoke is given off. Each girl boxes under a glass hood, and the fumes and smoke are immediately drawn down the back of the hood and under the table to the fan. You will note that in this case the air supply is not dependant upon the opening of windows, as air is forced into the room and discharged under the tables. The air is warmed in cold weather, and so unpleasant draughts are avoided.

Air Filtration.

In large towns it is desirable to filter the air before it passes into any building, but this is not so easy to do unless the air is forced in by means of a fan. Any kind of screen or filter would stop the supply of air, unless mechanical means were adopted for compelling it to pass the screen. Many experiments have been made with cotton and jute cloths, matting, &c., but none of these seem to approach in efficiency the coke screen seen in the illustration, Fig. 22. Two frames of strong wire netting are securely attached to a wooden support, about 5in. thick. The netting should be of about ¾in. mesh, and made from wire of 16's to 18's gauge. On the side furthest away from the fan a door is constructed at the top for filling with coke, and a door at the bottom for emptying. The screen should have a superficial area at least equal to six times the area of the fan used, The coke, before it is placed in the screen, should be carefully washed and passed through a 1½in. mesh, as the best size for the coke is about 2in. diameter. For cooling in summer water can be sprayed against the screen, and it can be washed down at any time with a hose pipe without disturbing the coke. All smuts and dust will be filtered out of the air, and even fog is very sensibly reduced by passing through the screen.

It is used at the Rylands' Library and many other important buildings with complete success.



FAN AND COKE AIR FILTER.

Fig. 22.

Drying.

Although drying is not necessarily included in this subject, it may be as well to give a hint as to what to avoid in fixing a fan for the ventilation of a drying room. Do not fix too large a fan, and do not fix it at the top of the drying room where it will remove all the best and driest air. Rather aim to circulate the warm air by means of the fan, and do not allow it to escape until it is incapable of absorbing any more moisture.

Conclusion.

In conclusion your attention is directed to a series of pictures taken from *Munsay's Magazine*, English edition for November last. They illustrate a factory in Dayton, Ohio, U.S.A., where they not only have a wage list of £200,000 per year, but each year a sum of £50,000, or 25 % of the wages is appropriated for the realization of what is called Utopian ideas.

The proprietor, Mr. Patterson, is said to be neither a poet nor a prophet, but a manufacturer who looks with contempt on philanthropy and values only what is practical. He says "Everything that makes my employee a better man gives me through him a better piece of work. It is never a question therefore whether to spend money for his benefit, but only how to spend it to increase his knowledge, his happiness or his health. Money spent to produce such results will bring as quick and sure a return as that invested in any other of the more customary ways of developing a business."

It is said that a few years ago the factory was as gloomy and as unclean as factories usually are, and with the most dismal surroundings. The workpeople were full of grievances and occasionally they had a strike. The work required skill and accuracy, but in spite of everything the superintendent could do the output was uncertain and unreliable, and one day instead of a cheque for £6,000 arriving from England a train load of defective machinery was returned. This seriously crippled the business and it was a question whether or no it should be discontinued.

Up to this time Mr. Patterson had only taken that distant interest in his workpeople which is supposed by many to be the proper attitude of the employer, but the ruinous condition of his business caused him to alter his plans. He went into the factory and worked and talked with his men. He found that nearly every employee knew of a hundred faults in the management, and was convinced that he could conduct the business better than the owner. He was surprised to find that many of the ideas were good, and if developed would become valuable. He dispensed with his superintendant or manager, and in his place he chose a factory committee from his workpeople, selecting those with the best mechanical education, and he gave this committee complete charge of the manufacturing department.

Each member of this committee served as its chairman for a month. Suggestion boxes were provided in which each workman could place any complaint or submit any invention or suggested improvement and the first year they had over 4,000 suggestions, and acted on 1,100, which they found practicable and serviceable. It was discovered that as the interest of the employees was appreciated and their suggestions made use of, their desire to be useful increased and frequent meetings of the whole of the employees were held, and at these they were asked to contribute to the general knowledge and share in the owner's plans.

Mr. Patterson noticed the untidy appearance of many of the girls with soiled and badly fitting clothes and untidy hair. He called the forewoman to him and said that all this must be altered. "Get two or three hundred curling irons and have them here in the morning. I will fix up a toilet room and if these young ladies can't comb their hair before coming to work they can do it when they get here. I want them pleasant to look upon and happy in their work, and we will do our share to bring that about." In a few days a decided change for the better could be seen in the girls and Mr. Patterson said "as long as such efforts as these produce results we will continue them." He had the entire Factory cleaned, chairs with backs replaced the old stools, windows were enlarged, and a soft and restful tint chosen for the painting. Pretty white aprons and sleeves were provided and washed every day at the owner's expense. A large atttic was converted into a dining-room where a model free lunch was served daily.

Every improvement acted directly upon the disposition of the workpeople and the effectiveness of their work, and so the efforts were continued outside the factory. A celebrated landscape gardener was sent for and he converted the dreary factory yard into an ideal garden plot. Then an effort was made to get the employees and all the people who lived in the neighbourhood to

beautify their homes. A landscape gardner was permanently employed and all could consult him without charge. Seeds were distributed freely and hundreds of prizes were given for the best front and back garden, the most beautiful division fence, the most artistic window box, and the best vine culture. The results have been thoroughly satisfactory and what was once a disreputable and unsightly portion of Dayton known as Slidertown is now South Park, probably the most beautiful manufacturing suburb in the whole world.

I shall now show you picture illustrations* of this wonderful manufacturing district. The first is a picture of vine-clad factories. You will agree that the buildings would be commonplace without the vines.

Fig. 23.

The next shows the houses in the vicinity of the factory, and these would satisfy any landscape gardener. Then we have a view of the cooking school, where the women employees learn to cook. The next, Fig. 23, is a charming picture showing the girls at work by the factory windows, with a view of the model

* These were shown on a Lantern Screen.

cottages outside, and lastly, Fig. 24, we have a view of the pretty dining-room, where the free lunch is served every day.

Fig. 24.

On being asked how he knew these things paid, Mr. Patterson said: "Everything we have done has immediately resulted in an apparent gain to the business. From the first move to the present day the cost of production has lessened and the quality of the produce increased in direct response to all we have done to add to the comfort, the contentment and enlightenment of our employees."

"Go thou and do likewise!"

DISCUSSION.

Mr. George Saxon said that although not an expert like Mr. Sutcliffe, he had been deeply interested in the paper. Though he could not criticise it from the point of view of an expert, there were one or two matters to which he should like to refer. He noted with pleasure that while Mr. Sutcliffe

pointed out that we were behind-hand in the ventilation and arrangement of our workshops, our workmen were not to be excelled. It was quite true that the curse of the last decade had been cheap goods owing to the amount of competition which existed.

With regard to the splendid picture Mr. Sutcliffe had drawn of the Canadian works, the kind of work was not mentioned, and it was not shown whether there was any competition in the trade. On another point it must be remembered that America was a protected country and that the manufacturer there had something in his favour on that account. This and other considerations entered into a comparison between British and American manufacturers, and might be one of the operating incidents enabling the American manufacturer referred to, to buy his steel in Sheffield and afterwards to sell his manufactured articles there. It was well to have such ideal manufactories as Mr. Sutcliffe had described, and it ought to be our endeavour to rise to the same level. There was no doubt about it that better conditions meant more efficient workmen; but at the same time it would be unwise to imagine that these things were going to bring about success in every industry. Mr. Sutcliffe's reference to loss through coldness of workshops in winter was proved by one's personal experience. He was much obliged for the hints which had been thrown out in the paper, many of which he thought would prove useful to them all.

Mr. T. Ashbury said they were under a deep obligation to Mr. Sutcliffe for bringing the subject of ventilation before them. It was one which affected everyone, and its importance had not been overdrawn by Mr. Sutcliffe, one iota. When the Royal Commission, sitting about the year 1858, on the barracks of the country issued its report, immediate action was taken to improve the ventilation of several large barracks. This met

with remarkable success, as the deaths from consumption which had been 11 % immediately fell down to 8 %, clearly showing the advantage of thoroughly efficient ventilation. It would not be right to criticise the paper too severely, because ventilation was one of the subjects upon which no rule or formula could be laid down which would apply under all conditions. Each case had to be dealt with in its own surroundings. He thought we had begun to learn that it was better to have air drawn into rooms in definite and known quantities than to have a haphazard system of ventilation. Could not this be done under most conditions without fans, by furnaces, stoves, and the like?

Mr. Henry Webb said reference had been made by Mr. Sutcliffe to cleanliness of workmen in shops in America. Perhaps in this respect arrangements that were the acme of perfection were to be found at Messrs. Brown & Sharp. There were one or two points in the paper which he did not understand. It sounded very well in theory in ventilating a closet to take three inches off the bottom of the door, and put a pipe on the other side to take smell away. But he found that the thing generally acted the other way about. Once he determined foolishly to build a house for himself, and told the architect that he wanted the ventilation particularly attended to. A fad was introduced into every room, but all of them proved abortions except one, and that was his own idea.—(Laughter.) He had a nine inch square shaft built in the wall from the cellar to the height of the chimneys, and connected with each room. By lighting a gas jet in this shaft, say in the bedroom, it drew all the foul air from the room below, and the ventilation was perfect. No down draughts. In regard to the ventilation of mills the difficulty was caused by the question of humidity. He once had a fad and it cost him a deal of money. Experts were employed and the case was gone into thoroughly, but

the whole of the appliances used had been thrown out except a few fans which Mr. Sutcliffe put in, and these only acted on a certain kind of day.—(Laughter.)

Mr. M. Ingram pointed out that while Mr. Sutcliffe asked that manufacturers should provide 2,000 cubic feet of air per hour for their operatives, the cottages in which the workmen lived only allowed 200 cubic feet. He ventured to think that the difference between the atmosphere in an ordinary workshop and in an ordinary cottage was in favour of the latter. He was not going to say that too much was asked of the manufacturer, but he suggested that attention should be turned to other classes of property as well. As regards the question of forced draught versus natural draught, he was of opinion that there was merit in both. But as it was a point on which ventilating experts differed, it was not wise for a layman to interfere. He would make one suggestion, however, and that was that the importance of good ventilation should be brought more prominently before the public, he did not care whether by means of lectures, entertainments or schools. It was a matter of utmost importance to the public at large in days when over-crowding was prevalent and jerry-building was rampant.—(Hear, hear.)

Mr. W. Ingham thought that the architects who, of all men should have an intimate knowledge of the subject, were very deficient in this respect. This was proved by the very inadequate and primitive means provided for ventilating churches and other large buildings. Two or three "tin cans" on the top of a public-meeting room were often considered sufficient to carry off the foul air, while as often as not one or more merely served as an opening down which cold air tumbled on the heads of the unfortunate people sitting beneath. He criticised ventila-

tion obtained by the radiation of heat from steam pipes as a roundabout system, and suggested that air should be heated in a more direct manner. With regard to purifying air passed into a room, if it were driven with any considerable velocity through any sort of screen he maintained that the finer particles of dirt would not be extracted. One objection to heating air to any considerable temperature was that its capacity for moisture was rapidly increased, and that was why he thought that to a considerable extent hot air heating had gone out of use. If one could, as air became heated, introduce automatically the moisture required by the air to render it suitable to breathe at the higher temperature, hot air heating would rapidly come into use again. He believed that in the immediate future this was about to be done.

Major Roe, H.M. Inspector of Factories, said the last part of Mr. Sutcliffe's paper contained a beautiful picture of a factory in America. He thought this country could show equally good cases, if one were to pick them out. Cadbury's chocolate works might be mentioned as a case in point, and he remembered being at Messrs. Lever Brothers' sunlight soap works once and seeing the workpeople haymaking in their own fields. He did not think in the matter of factories we were behind America or any other country except in one thing. We had been the pioneers in manufacturing, and to some extent we were suffering for it, for while we were often working with old machinery, where industries were being newly started the very latest appliances could be introduced. The cost of replacing old machinery with new in our mills was too great to be suddenly brought about. For the same reason some of our older buildings were not so well ventilated, and had not such perfect sanitary arrangements as those which were now being put up.

Some 14 years ago the case of a gentleman who carried on a trade in a number of old dwellings turned into a factory came to his notice, and he had often to worry him about ventilation and overcrowding. At last it was determined to build a new factory in the suburbs, and a system of ventilation, not so elaborate, but on the same lines as that mentioned in Mr. Sutcliffe's paper, was carried out. The air was allowed to flow in through shafts about six feet high in the room, and was extracted by fans. The air was in cold weather first heated over a furnace, and he might say that this was the only way of warming the building. He had been in the place on the hottest days in summer and found it beautifully cool, and in winter comfortably warm. The mention that had been made of the falling off of cases of consumption in the army showed that we were at one time absolutely poisoning our soldiers by not giving them sufficient fresh air. Previously they had only had 300 cubic feet per head, but after the Commission it was decided to increase the space to 1,000 cubic feet, with the result that consumption almost absolutely ceased in the British Army.

There was one thing that ought to be remembered in ventilation, namely, that air was moved by friction. If they drove a current of air through a small pipe along a room, they would find that the air in the room was drawn the same way by friction. That was a very important point in getting rid of dust. He agreed with what Mr. Sutcliffe had said about the use of fans in drawing away fine particles of dust thrown into the air by certain manufacturing processes, frequently to the injury of the health of the workmen. In one case which he had in mind, the hair and nostrils of the operatives were filled with emery dust and brass filings. He advised the firm to put in a fan, and afterwards had the satisfaction of being told that the fan had not only paid for itself, but that the brass filings which before had been lost, had become a source of profit in the jewellery trade.

Mr. WALTER YATES said the great point to be aimed at in ventilation was to get the air to enter at one end of the room and out at the other. In Mr. Sutcliffe's paper they had an illustration of the system adopted at the Bury School of Art. This was, to his mind, one of the very best methods which could be adopted. If a room were to be properly ventilated, fresh air must be supplied at a proper temperature to take the place of that extracted. He agreed with Mr. Sutcliffe that if bigger sums were spent on heating and ventilation we should have much better health in our workshops.

Mr. JOS. NASMITH, in moving a vote of thanks to Mr. Sutcliffe, said he was convinced that the system of forcing air into a room, heated if necessary, and humidified if they liked, was the proper one to pursue. The whole principle of ventilation was laid down in the sentence that "the difficulty lay in controlling air currents." The question of draughts was purely and simply one of proper distribution. What was wanted was to let in air over the whole area of a room so as to sweep every corner. The question hinged on the fact that one could not have anything for nothing in this world. If they wanted ventilation they would have to pay for it. The old fashioned idea that making a hole or two in a wall and putting in grids with "a few flopping things on"—(laughter)—was sufficient, had got to be knocked on the head. In cases where air had to be driven long distances to ventilate a number of rooms, in his opinion the ordinary type of air propellor was not strong enough, and must be assisted at various points with extraction fans. Turning to the cost of ventilating mills and workshops, he said it was a fallacy to say that employers could not afford it. Many years ago the late Mr. Edwin Chadwick, in a paper which he read before the British Association or the Social Science Congress on the value of health, proved to a demonstration that the

amount of money manufacturers lost by reason of the ill health of the workpeople was, in itself, very considerable. This was a phase of the question which deserved more attention than it got.

Mr. H. Webb seconded the resolution, which was carried.

Mr. Sutcliffe, in reply, said he was particularly pleased to hear Major Roe's opinion on the subject of ventilation, as from his experience as a factory inspector he must have seen thousands and thousands of workshops. As to Mr. Nasmith's reference to the use of pressure fans as against open volume fans, he (Mr. Sutcliffe) thought pressure fans could be done away with to a great extent, if sufficiently large ducts were provided. It was better, if possible, to make the ducts large in the first instance, and thus save the difference in power, as frequently a pressure fan absorbed ten times the power of a volume fan in moving the same amount of air. Both types of fans have their proper work, and when the resistance is over half-inch W.G. a pressure fan should be used.

Replying to Mr. James Saxon, Mr. Sutcliffe said the American Factory he had described was manufacturing Cash Tills, and had plenty of competition.

THE FUTURE DEVELOPMENT OF THE STEAM ENGINE.

(A FORECAST.)

READ SATURDAY, 10TH FEBRUARY, 1900,

BY

MR. ALFRED SAXON, M.I.MECH.E.,

(MANCHESTER).

It is a fitting time in the closing year of the nineteenth century, or the first year of a new century—whichever may be correct—to estimate the achievements of the nineteenth century.

In our case, it is to observe this evening the progress of the steam engine, with a view of gauging from this evidence the probabilities of its future development. Anyone following the records and traditions which relate to the steam engine, will have their attention drawn to the fact that history repeats itself time after time, in fact, it would be quite true at this stage of its history to say that there is nothing new under the sun. There is also a very important truth demonstrated, viz., that great inventions are never, and great discoveries seldom, the work of any one mind; every great invention is really an accumulation of minor inventions, or the final step of a series, so that it is not so much a creation as a growth.

It will only be possible this evening to deal generally with the various types of steam engines, but I may say that in *all* these various types the direction of general progress is the same. In locomotive, marine, and stationary engine practice, the use of HIGHER STEAM PRESSURES, GREATER EXPANSION, PROVISION FOR OBTAINING DRY STEAM, HIGHER PISTON SPEEDS, AND PROTECTION AGAINST RADIATION AND CONDUCTION LOSSES, have tended in a remarkable degree towards economy.

In other directions than in economy and in the principles of working, wonderful progress has been made in the steam engine. There has been quite a revolution since the commencement of the century in the variety, quality, and strengths of the materials of which the engine and steam producing plant have been constructed; there has also been a great increase in the size and power of these plants. The machine tools for working the materials have been much improved, thus enabling greater accuracy to be obtained, and dispensing as far as possible with hand labour, except for the fitting and adjusting of the various machined parts to each other. Especially has it been possible to produce more accurately bored cylinders, and more perfectly fitting pistons and valves, thus minimising those losses due to leakage to a very considerable extent. I need only refer to the Willan's engine to instance what has been accomplished in this respect.

A better knowledge of the principles of the steam engine has been acquired. The strengths of the various materials available have been properly tested, and the results tabulated. The mechanical draughtsman of to-day designs the various parts of the engine with the knowledge of the stresses and strains to which they will be subjected, thus enabling the parts to be made more symmetrical, and avoiding undue weight—this is a most important point in high speed and marine practice.

The principal points of progress are :—

1st. Higher Pressures.

2nd. Greater Expansion.

3rd. Increase in Speeds of Piston and Rotation.

HIGHER PRESSURE.

With reference to higher pressure, early marine practice—like the steam pumping engine, and mill engine practice at the beginning of the century—involved the use of steam at little

more than atmospheric pressure. The increase in pressure for many years was very slow, but progressive. Since 1870, when boiler pressures were about 75lbs., there has been a very rapid rise, particularly in marine practice, which, at the end of the century, has in some special cases reached 300lbs. pressure.

The marine practice of the last half of the century can fairly lay claim to having been the greatest factor in the progress of the steam engine.

Sir William White, in an address as President of the Mechanical Science Section of the British Association, in a review of the progress of steam navigation says :—

"Sixty years of continuous effort and strenuous competition on the great ocean ferry may be summarised in the following statement. Speed has been increased from 8½ to 22½ knots; the time on the voyage has been reduced to about 38% of what it was in 1840. Ships have been more than trebled in length, about doubled in breadth, and increased ten-fold in displacement. The engine power has been made forty times as great. The ratio of horse-power to the weight driven has been increased four-fold. The rate of coal consumption—measured per horse-power per hour—is now only about one-third what it was in 1840. To drive 2,000 tons weight across the Atlantic, at a speed of 8½ knots, about 550 tons of coal were then burnt; now, to drive 20,000 tons across at 22 knots, about 3,000 tons are burnt. With the low pressure of steam, and heavy, slow moving paddle engines of 1840, each ton weight of machinery, boilers, &c., produced only about 2 HP. With modern twin-screw engines and high steam pressure, each ton weight of propelling apparatus produces from 6 to 7 HP. Had the old rate of coal consumption continued, instead of 3,000 tons of coal, 9,000 tons would have been required for a voyage at 22 knots. Had the engines been proportionately as heavy as those in use sixty years ago they would have weighed about 14,000 tons. In other words,

machinery, boilers, and coals would have exceeded in weight the total weight of the Campania as she floats to-day. There could not be a more striking illustration than this of the close relation between improvements in marine engineering and the development of steam navigation at high speeds."

I shall not attempt to institute a comparison of the advances of stationary engine practice on the lines of the review I have just quoted, as I feel that the only lines of progress in common are those which I have already indicated.

Stationary engine pressures in 1870 were considered high, even at 100lbs. The following quotation from a lecture on the steam engine, given by my father in 1873, before this very Association, accentuates this fact:—

"Whilst speaking of boilers, I may just remark that two or three years ago, having taken a contract to supply a pair of compound engines, and my customer having determined upon giving the order for the boilers to a firm who made them their special business, he introduced me to the senior partner of the firm in order that I might explain to him what kind of boilers it was desirable that he should supply. I insisted that they must be plain, practical, simple boilers, and to carry a working pressure of 100lbs. to the square inch. The greatness of the pressure caused him to shake his head, and ultimately he took a week to consider it. At the end of this time we met again; he smiled, and produced his specification, which was accepted."

In both locomotive and stationary engine practice, at the present time, pressures up to 200lbs are in daily use.

GREATER EXPANSION.

Our next point of progress, greater expansion, has now to be examined. The adoption of higher steam pressures allowed engineers to avail themselves of the expansive properties of steam, and to provide for the utilisation of the greater range of

working temperatures, and to reduce initial condensation in the cylinder. The compound type of engine was introduced about the year 1854, in a practical form, followed by the triple, in marine practice, about 1874, and later by the quadruple type. Each of these types became practical and economical under suitable conditions of boiler pressure. The idea of introducing additional cylinders to obtain greater expansion has not been adopted to any large extent in locomotive practice. To show how comparatively recent was the adoption of triple and quadruple expansion engines in land practice, I would refer you to the Jubilee Exhibition, held in Manchester in 1887, when examples of simple and compound engines *only* were shown by the leading makers.

INCREASE IN SPEEDS OF PISTON AND ROTATION.

Coming to our third point of progress—Increase in speeds of piston and rotation. The advantages of high speed steam engines have now been well recognised, as they provide a means of obtaining considerable power at a small initial cost; they are capable of being combined direct with such machines as dynamos, centrifugal pumps and fans, thus avoiding the loss of power in the latter and economising space, and can be easily worked in connection with a condensing plant, ensuring the greatest economy.

The Willans type single-acting constant thrust was for a time the only successful type of high speed engine, but since the introduction of forced lubrication, the high speed double acting engine has proved to be a success in its noiseless working and increased efficiency.

The increase of piston speed during the century has been common to all types of engines—locomotive, marine and stationary. Locomotive is ahead of marine and stationary practice in speed of piston: from 750 feet per minute for

ordinary practice, up to 1,500 feet per minute for exceptional high speed practice has been attained. Marine practice comes next, varying from low and moderate speeds of 425 feet to 600 feet per minute, to high speed and extreme practice in such craft as torpedo boats from 850 feet to 1,200 feet per minute. In stationary engine practice we find piston speeds to vary from 500 feet to 1,000 feet per minute; this will cover the ground of slow revolving engines of long stroke as well as quick revolving engines of short stroke.

Incidentally I may remark that the Glasgow Corporation engines are intended to run at a speed of 75 revolutions per minute, with a stroke of 5 feet, thus giving a piston speed of 750 feet per minute.

ECONOMY.

In connection with the distinct lines of progress referred to, we find the gain in "duty" to be the best measure of progress: the greater amount of useful work performed by the unit of fuel consumed has been progressive, and has obviously increased with the rise of the steam pressure.

The gain in economy during the nineteenth century has been considerable. The consumption at the commencement being from 8 to 9lbs. of coal per IHP per hour; whereas, at the present time, in the best type of engine, it has been reduced to 1½lbs. per IHP, and even lower in extreme cases.

The nineteenth century has a record of many improvements to which it is impossible to refer in the short time at my disposal, but I should like to state that the introduction of continuous lubrication to valves and pistons and the principal working parts of the engine has been of great service and has contributed to increased efficiency.

And now, Mr. President, after this review I shall venture to enter into the forecast that my title demands.

FORECAST.

In the first place it will be well to see what the probabilities of the new century are in reference to the direction of progress. We have noticed that marine practice has exercised the greatest influence on the progress in the nineteenth century, but in the new century the demands for electricity are likely to be the principal factor.

To-day we are face to face with the problem of producing electricity for all purposes at a sufficiently cheap rate. In this country we are handicapped in our competition with other industrial countries by the fact that only to a limited degree can we use water power for the direct generation of electricity; it becomes, then, a matter of vital importance to this country that the steam engine and steam producing plant intended for the generation of electricity in the future should be brought to the highest degree of perfection possible.

PRESSURE.

First, with regard to pressure, the steam pressures adopted will be as high as the materials and construction of the boilers will admit of; I have no doubt that with a revolution in boiler construction, which we may confidently expect, that standard pressures will rise up to 500lbs., and probably even higher.

GREATER EXPANSION.

With the adoption of the higher pressures mentioned above, the system of expansive working will be more utilized, but must be subject to certain limits with regard to the number of cylinders employed. Probably it will not be found necessary to go beyond quadruple expansion even with the high pressures now suggested. When we consider that in locomotive work, in simple engines pressures up to 200lbs. can be used, it does not seem necessary to multiply the number of cylinders but to regulate the point of cut-off and the proportions

of the various cylinders employed to each other, to utilize the expansion of the steam to the fullest practical extent.

INCREASE OF SPEEDS.

With reference to engine speeds, the double-acting vertical type, with forced lubrication, has opened up great possibilities in this direction; there is a limit to the velocity of the reciprocating parts of such an engine, but this does not seem to have been reached as yet. With stronger and lighter materials available, which will be produced as the necessity arises for their use, and still greater attention paid to the more perfect balancing of the rotating and reciprocating parts, higher speeds will be attainable, and I have not the least doubt that in stationary land practice we shall be able to approach the high speed of 1,500 feet per minute.

ECONOMY.

Dealing with economy, reliable tests of the best steam engines of to-day show a steam consumption varying from 12 to 10lbs. of steam per IHP per hour, or say $1\frac{1}{2}$ to $1\frac{1}{4}$lbs of coal.

The gain in economy in the new century must be very gradual and comparatively small; no doubt if the gain were taken upon a percentage basis, we might reasonably predict a saving approaching to 50% on the present steam and coal consumption. The probabilities of the new century in this respect seem to be to reduce the steam consumption to about 8lbs., and the coal per IHP per hour down to 1lb. or even to $\frac{3}{4}$lb. of the best fuel burned under the most efficient conditions, in the newest and best types of boiler plant.

SIZE AND TYPE OF ENGINES FOR STATIONARY PRACTICE.

From experience already gained, it would seem that for lighting and electrical traction, the use of very large units of power will be most economical, not simply in economy in coal consumption, but in a great many ways in connection with the

standing and running charges of these large central stations. I shall not attempt to describe the Glasgow Corporation engines, the order for one half of which has gone to America, and the other half to a Lancashire firm, but this instance will serve to show the magnitude of the present day schemes, and in all probability the units of power adopted in the scheme referred to above, viz., 5,000 IHP, will be well up to the producing capacity of the machine tools in our stationary engineering works at the present time, and I have no doubt that units of 10,000 IHP will be the limit for many years.

I have just referred to what public enterprise is doing in relation to electric power, but how will the general industries of the country be influenced by the progress of electricity? To judge by the signs of the times in America, and in this country more recently, there will continue to be a growth of combination and the formation of trusts in industrial circles, which will have the effect of introducing large schemes for lighting and power.

The direct-acting inverted vertical engine with the cylinders arranged for expansive working, has proved its adaptability to meet existing conditions in central power stations, and with still higher steam pressures and increased piston speed, together with the application of forced lubrication, is, in my opinion, the engine that will meet the new century's demand in this respect.

I predict that engine makers in the new century will make a great point of standardizing and classifying their engine designs, and that suitable units of power will be adopted to meet the varied demands.

I am also of opinion that the use of small steam engines and engines of moderate sizes working at low pressures will be discarded, or the latter altered before the first quarter of the new century has expired. Only compound, triple, and quadruple expansion engines of the best type will be used, and these in

most cases for the generation of electricity, for its application to the driving and lighting of our industrial works and factories.

SUPERHEATING AND RE-HEATING.

The various types of engines referred to above will, in my opinion, be arranged to work at the highest possible pressures with superheated steam. There is no doubt that for general and practice, with a view to utilizing the present type of Lancashire boiler—which is not suitable for pressures greatly exceeding 200lbs.—that in the immediate future superheating will be more generally adopted; it has been extensively adopted in Continental practice, but up to the present time only to a limited extent in English practice.

I forecast the general adoption of superheating and reheating in land practice before there is a resort to much higher pressures than are now in use: after the fullest benefits have been secured from this source there will come the demand for higher pressure.

STEAM TURBINE ENGINE.

The steam turbine engine is likely to be a formidable competitor in electrical work, but on account of its high speed will not prove so universal in its application as the reciprocating steam engine. Simplicity in the valves and valve gear seems to be the lesson which the steam turbine engine teaches the reciprocating engine builder, and in this respect a diminution of cost and wear and tear will probably be arrived at without interfering with the economy of the steam engine; although the governing cylinder will still, of necessity, retain valves and valve gear for the measurement and control of the steam to be admitted for work to be done during each stroke, *still I venture to forecast the abolition of the valves and valve gear of the succeeding cylinder or cylinders.*

If it is possible to use steam economically through a steam turbine engine, and to utilise the system on the compound

principle to gain the advantages of the expansive properties of steam without the aid of the elaborate and oft-times cumbersome valve gear now in use, surely it is possible to advance in the same direction in the ordinary reciprocating steam engine. In fact as our piston speeds increase a simpler system will become more and more imperative.

STEAM LOCOMOTIVE PRACTICE.

In locomotive practice I consider that although modern steam locomotives are not particularly wasteful, and that up to now the electric locomotive has been more or less of a failure, yet I believe the steam locomotive is doomed to extinction in the new century. The steam tram engine cannot compare with electric car traction worked from a central station, and in the same way, I am of opinion that with generating stations on a large scale, placed at suitable distances apart on our main lines, electric traction will gradually supersede steam locomotive traction.

In London we have electric traction at work on various lines; in Liverpool, the overhead electric railway; Blackpool to Fleetwood electric tramway; we have the scheme of the Manchester and Liverpool electric railway proposed, and other schemes in actual operation in various parts of the United Kingdom. In the U.S.A. immense power stations are being constructed to deal with local railway and tramway traffic.

MARINE PRACTICE.

In marine practice, electricity does not seem to be available for distributing the enormous powers developed, but for auxiliary purposes such as lighting and hoisting, and in a hundred different ways it will be of service. Herein, also, the great competitor to the reciprocating marine steam engine will be found in the rotary steam turbine engine; in Cassier's Magazine of July last, in an article contributed by the Hon. C. A. Parsons, he

claims that the turbine engine in its more perfected form may supersede the piston engine in many of the most important fields of motive power, in which, until recently, the latter has enjoyed a monopoly.

And now, gentlemen, I would say that our position in the industrial world during the greater portion of the nineteenth century has been created and maintained by the superiority of our coal and iron supplies.

Great as have been the achievements of the nineteenth century in the perfecting of the steam engine, and although we have approached considerably nearer the goal of theoretical efficiency than many of the old engineers would have thought to be possible, still there lies before us a great victory over waste. We are all quite aware that a great waste of coal is still taking place in most of our industries, due to the fact of its having been so cheap until recently, a fact which has encouraged the continued use of engines and steam producing plants of low efficiency. We waste by not pursuing scientific methods, and from our lack of adapting ourselves to the changing requirements of the age. We must consider the lessons we have been and are being taught by foreign competition, and be determined to reconsider and revise our methods where necessary or advisable. If we apply to this problem the requisite amount of patience and theoretical and practical knowledge which is available, we shall continue to economise and conserve those natural gifts which have, up to the present moment, enabled this country to hold its own against all comers.

DISCUSSION.

The PRESIDENT (Mr. Henry Hodgson) said that generally speaking he thought he could support the paper, although there might be some parts of it with which he could scarcely agree. The paper showed pretty well what might be expected in steam engine development during the coming century. In one part, however, Mr. Saxon talked about dispensing with valves when they got beyond the high pressure cylinder. He (the speaker) did not see exactly how that might be done. Perhaps Mr. Saxon would explain.

Mr. M. INGRAM said he agreed largely with Mr. Saxon when he kept to the retrospect, but when he assumed the mantle of prophecy he (the speaker) thought the man in the street would probably know as much about it. It was perfectly right to assume that evolution in the steam engine was still going on. Mr. Saxon was making an exceedingly safe prediction when he prophesied that steam pressures would be as high as the material and construction of the boilers would admit.

As the gain in economy in steam was to be so very small, would it not be well to look for some other source of power, as for instance the large amount of water that was now wasted, and which constituted a potential force which only wanted harnessing to be utilised for work.

Mr. JOSEPH PARRY said the author predicted a rise to 500lbs. pressure. The heat in steam at that pressure would not be very much greater than at 125lbs. The temperature of steam at 125lbs. was 353° Fah., and at 250lbs. 406° Fah., a difference of 53°, and the difference between the temperature at 250 and 500lbs. was smaller than that.

The author talked about high speeds, pressures of 500lbs. at speeds of 1,500ft. per minute. Now very great pressures were not consistent with very great speeds, and this made itself evident at much lower pressures than 500lbs., with much lower piston speeds than 1,500ft. Mr. Saxon said that the strengths of the various materials had been properly tested, and and the results tabulated. The results of ultimate tensile stresses could be got by the mile, but they were of very little use to the mechanical draughtsman. The mechanical draughtsman, or anyone else who was responsible, did not want to know what stress would produce sudden collapse, but under what stress the article would live, and if they referred to previous practice they would find all sorts of results. More experiments with repeated stresses were required. This applied especially to the different classes of steel.

Dr. Nicolson said that to a large extent he agreed with the author as to the directions in which he indicated progress. What he (the speaker) had to say would be directed more towards altering the ideas people usually entertained with regard to the reasons why economy and progress followed certain lines. Along with a colleague in Canada he had had the privilege of reading a paper before the Institute of Civil Engineers about two years ago, "on cylinder condensation," and in the course of experiments they made in connection with that paper they found out some things which, although not as yet very strongly confirmed, should, if true, be more widely known. One particular point they discovered was that the leak of steam past the valves from the steam chest into the exhaust without going into the cylinder at all was much more extensive and important than was perhaps generally imagined. In studying this matter, they not only tested two or three different types of valves directly for leakage, but inferred the leak as incidental

to the method of the research. This method consisted in taking the temperature of the cylinder wall, and finding the amount of steam that must have been condensed in the cylinder to account for the heat which actually went into the cylinder wall. Knowing then the amount of steam that was actually condensed, from the amount of heat they knew went into the cylinder wall; and subtracting what was accounted for by the indicator, and what was known to have been condensed on the wall, from the total amount of steam which the engine actually used, the difference, according to their argument, must have been what leaked straight across the face of the valve from the steam chest into the exhaust. In a 60 HP high-speed engine of American type with automatic cut-off, they found that the leak must have been about 500 to 600lbs. per hour. They actually measured the amount of leakage of 300lbs. per hour by blocking the ports, and reciprocating the valve under steam, and inferred a much larger leak when the engine was running under normal conditions. They also came to the conclusion that this leak took place in the form of water, *i.e.*. that there was simply a flow of water across the valve face. They inferred that if they could prevent that water forming, and make any leakage occur in the form of steam the leak would be much diminished. If, therefore, they could heat the valve face or superheat the steam they would destroy that method of leakage, *i.e.*, in the form of water, and this fact, they inferred was really the cause of so many of the economies that were attributed, wrongly, to other causes.

It was usually supposed that the increased economy in high speed engines was due to diminished initial condensation. Well, in the first place, it was rather problematic to say that high-speed engines on the whole were more economical than low-speed engines. The reason why they were so successful, was, he submitted, the less first cost, &c. In high speed

engines they had to have a very large port area in order not to wiredraw the steam too much. The result was an enormously increased leak, so that a high speed engine *per se* ought not to be as economical as a low speed engine with the same type of valve.

Again, the economy due to jacketting, which was resorted to diminish condensation, was not owing to that fact but to the conduction of heat from the jacket along the metal into the valve faces. There was a consequent heating of the valve faces and a diminution of the leakage. In order to prove this they made an experiment which was quite convincing in its results. They were able to superheat steam sufficiently to heat the valve faces 20° above the saturation temperature, and the leak they measured was reduced from 300 to 120lbs. an hour from the mere fact of superheating the steam.

He might also refer to the great improvement Parsons effected in his steam turbine by superheating the steam. At first he used saturated steam. In Parsons' turbine there was a very great length of narrow gratings through which the steam had to get, and if the steam was saturated and these gratings became full of water from the condensed steam, there would be a very considerable leak in the form of laminar flow, but if the steam were superheated this leak would be reduced enormously. The question of leak seemed to him to be an extremely important one, and deserving of more attention than it usually received.

He believed rather in going in the direction of paying more attention to the design of valves than to diminishing their number. The fact why the Corliss engine was so much more economical than most others was not due to the sharp corner at the cut-off, but to the fact that there were two valves, or two preventives to leak. Leakage could not take place from the steam chest to the exhaust in the Corliss engine, except for

a short portion of the stroke, but only into the cylinder, and then out of the cylinder to the exhaust.

They ought to attempt to heat the valve faces. He believed a type of valve such as the Sulzer was likely to be a much less leaky valve than the Corliss, or the slide valve. At the Technical School, where large laboratories were being equipped for research purposes, &c., they were going to have a large compound steam engine specially fitted for testing this very point, viz., the leakage of valves. There would be three types of valves—slide, Corliss and Sulzer—and every facility would be provided for actually measuring the amount of leak that took place.

Mr. Philip W. Robson said the author, at the commencement of his forecast, among other important matters, referred to the boiler. It would have been interesting to know in what direction the author anticipated improvements in the boiler. As things were now, he was afraid the development of the boiler did not receive the same attention that was accorded to the engine. In the design of the latter every care was taken to elaborate the details, but too often in connection with boilers they were content to accept what had been given to them for several years past. Of course they had seen during recent years the introduction on a very large scale of water tube boilers, but even there he was afraid they had been content with too little. They had been forced to accept articles on the market simply because they were the only ones available, although they were very often inferior articles and totally wrong in design. He thought there was a great deal to be done on the question of boiler design. The laws of transference of heat between fluids and metals and *vice versa*, which had been so ably enunciated by Professor Osborne Reynolds, of Manchester, might be applied with considerable advantage to the design of the boiler, and that was a direction in which he

ventured to think they might look for improvements. He had recently seen a small surface condenser designed on these principles, and in which of course similar problems of heat transference occurred as in the boiler, and he might say that even in its present imperfect state it was capable of doing at least twice the work, for its capacity, as one of the ordinary design.

As to piston speeds in marine practice, to which the author had referred, he might mention that he had had a considerable experience in marine engine design, and he might therefore point out to them that the highest limits were only applied under exceptional conditions, that was, to ships of the Navy and special passenger ships. In Navy ships where a great deal of power had to be got into a small space it was certainly essential to go in for very high speed engines with great piston speeds, but these were not by any means the most economical as working jobs, and in ocean liners and ships where they were not so much tied down by considerations of space, more moderate piston speeds were adopted, and with success. In fast running engines, to get any degree of success whatever, great elaborations of detail must be aimed at, and that did not always pay. As to balancing, so far as he knew, there was only one efficient method of balancing ordinary reciprocating steam engines, and that was the Yarrow, Schlick & Tweedy system, which was very successful in marine practice. There was no reason why it should not find its way into stationary engine practice. By that system, adopting four cylinders. with four cranks, and placing cylinders in a certain way, and fixing the crank angles so as to give the desired result, all the free forces were to some extent eliminated, and in many designs eliminated altogether. He referred to the free forces due to reciprocation, the couples, and the connecting rod. If they went in for large engines running at even moderate speeds, they must go in for balancing which had a great effect on the

working of the engine. It meant less wear and tear on the bearings, and was altogether a most desirable thing in all classes of engines which were intended to work for any length of time. He begged to draw their attention to this matter, as in the large units which were at present being introduced for electric current generation, in which the dynamo was direct connected to the steam engine, any rocking or vibration produced sparking at the brushes, and other undesirable features.

Mr. A. L. Mellanby said it was astonishing to find the amount of ignorance that existed upon the question of the steam engine, and how easily satisfied, until a comparatively recent date, everyone had been with the performance of that machine. He thought that this ignorance and the inefficiency of the steam engine were both, in a measure, due to the lack of sympathy that existed between engineers and scientific men. The latter had attacked the mathematical problem of the steam engine, but it was a steam engine that existed in imagination only. They had made most elaborate theories of the thermodynamics of the steam engine, but, although they were surrounded by actual engines, very few had ever troubled to verify their theories. Of the few who had made experiments most of them had started with their own idea of what they wanted to prove, and had generally made their experimental results to suit.

On the other hand very few practical engineers in this country took the trouble to find out what men of science were doing. Mr. Robson had alluded to Professor Osborne Reynolds' work on the "Transmission of Heat"; how many boiler makers, he would ask, had studied the laws enunciated by Professor Reynolds, and had attempted to make a boiler where the knowledge so gained could be applied.

He could confidently assert that very few of the leading engine builders in this country knew anything about the performance of their engines. They had engines to build, and built them simply because people wanted to buy them. They would give a guarantee to the second decimal place of their consumption, but it was in the hope that as engine trials were difficult to make they would not be carried out.

He thought that the expected increase of economy due to greater boiler pressure was often greatly exaggerated. It was easy to state that if they got so much work at 100lbs. pressure they could get so much more at 500lbs. pressure, and the gain appeared to be enormous. Losses due to leakage and condensation were however entirely ignored in the calculation which was, of course, altogether worthless. In testing some quadruple expansion engines he had found that by raising the pressure from 170lbs. to 250lbs. they could only expect a gain of ½lb. of water per HP per hour. As the rate of gain became less as the pressure increased that did not point to any great economy from the higher pressures.

Dr. Nicolson, in the paper to which he had referred, brought before the world the first reasonable theory of the steam engine that had as yet been made. He had shown that the behaviour of steam in an engine was no longer attended with the mystery usually attributed to it, but that it could have the same laws applied to it as to steam in a piece of physical apparatus. When Dr. Nicolson was able to pursue his researches and to confirm the results he had already obtained, he would be able to bring forth a perfect theory. He thought it would be very appropriate if Manchester, which had done so much for thermo-dynamics through the work of Joule, should provide the experimental engine to give so great a result.

Mr. W. Ingham observed that Mr. Alfred Saxon's father was one of the pioneers in perfecting the compound engine in this district.

In his opinion development would go on for some time rather as the result of experimental and carefully conducted tests than in the way of the advantages that appeared possible from higher pressures. When they considered the diminishing ratio in which economy was possible by further increasing the pressure, they could scarcely look forward to very great results by proceeding in that direction to the extent indicated by Mr. Saxon. It was for a long time a mystery why a steam engine with apparently excellent indicator diagrams should sometimes give very poor results as regards economy, whilst in other cases, where the diagrams were much poorer, the actual results obtained were better. At the time he referred to, sixteen or eighteen years ago, the effects of cylinder condensation were not fully recognised. One of the first steps by which it was recognised, and steam leakage discovered, was the practice that began to prevail of putting on the saturation curve, and comparing it with the results shown by the indicator diagram. The nearer they could approach in the steam engine diagram to the hyperbolic curve the better results in economy it was found could be obtained.

There was a great deal to be done in dispelling the ignorance which prevailed, not only amongst steam users but amongst engineers, as to the means by which economy could be effected. When one went about the country and saw so many engines working non-condensing, it was surprising that it was not better known that engines could be worked condensing where there was sufficient water supply to provide steam for a non-condensing engine. Evaporative condensers were yet far from perfect, but it was possible to convert any non-condensing engine into a condensing one.

It was becoming the custom for steam engineers to give guarantees, and he was pleased to see that steam users, in many cases, were now preparing to go to the expense of having carefully conducted tests, which would well repay the outlay they involved.

Such tests as these and the investigations suggested by Dr. Nicolson for finding out what was taking place in the inner workings of the steam engine, would do more perhaps than anything else towards perfecting the operation of the steam engine, and securing increased economy.

Mr. T. Hilditch said there was a great deal of heat thrown away from engines which might be easily used to advantage. It ought to be very easy to design a superheater which would be steam tight and remain so, working at say 500 or 600° Fah., and not be effected even by 1,000° Fah. occasionally. Supposing the high steam pressure in the first instance was 400°, and this was reduced down to 150 or 200lbs., they might send that into a chamber, through which the waste gases from the boiler passed, and superheat it; then pass it back again to a second engine, and superheat it even to a third time, if need be. They would by that means gain very great economy in the way of fuel, and economise the steam to a far greater extent than by simply using a compound engine. This method would not be available, however, for all apparatus; it would be mainly applicable to apparatus where there was a practically uniform load.

Mr. Jos. Butterworth said the range of the paper rather militated against it. It would have been better to have confined it simply to some definite point, or, say to stationary engines. Owing to the range of the subject the author had not been able to attack with sufficient definiteness any one point.

It was important to keep down the factor of $\frac{\text{surface}}{\text{volume}}$ to its lowest possible limit. He believed three-quarters of the improvements available in the present engine would proceed from that source. They would have to get the cylinders as large as possible—that meant as large units of power as possible—and a longer stroke in proportion to the cylinder, so that the mean position of the piston would be with the diameter of the stroke equal, which he believed to be the position in which the greatest volume for a given surface could be got in a given cylinder.

More perfect jacketting was simply a means to the same end, viz., to stop the condensation.

Another point which had to be looked at in improving the engine was the balancing of the valves and various parts of the engine so as to reduce internal friction, so that the fraction of $\frac{\text{frictional H.P.}}{\text{total H.P.}}$ should be as small as possible. They might adopt 8, 9, or 10 cylinders to reduce the range of temperature in each cylinder, but they would spoil the fraction of $\frac{\text{surface}}{\text{volume.}}$

The economy of Parson's turbine was due mainly to the fact that steam flowed through always in one direction, and the fall in pressure at each point was small, so that they practically had the steam at the same temperature in each part of the machine. In the ordinary reciprocating engine there was a great difference.

Superheating was a good thing if it could only be designed so as not to militate against the mechanical efficiency of the engine.

Mr. Jas. Hartley said the question appeared to him to be whether we were getting out of the present steam engine that economy that might be obtained. He did not think we were, and in going about Lancashire and other counties he found that

at some of even the best places they were getting very poor results out of their engines compared with what could be obtained.

Then again, the question of jacketting was studied and the system adopted at one time far more than to-day. He believed that if they had a proper system of steam jacketting, say in the intermediate and low pressure cylinders of a triple expansion engine, and the steam were thoroughly broken up and superheated on its passage between the high and the intermediate, and the intermediate and the low pressure cylinder they would get rid of a great deal of condensation that was at the present time carried through the low pressure cylinder, and put into the condenser in the form of water.

As to the leakage of valves, it was no doubt a very serious matter, but in a multiple engine it was not of the same importance as in a single cylinder engine. That was, as regards the first and second cylinders; but in the low pressure cylinder of multiple cylinder engines it was a matter of very great importance indeed. In triple and quadruple engines they found a great amount of condensation carried forward from the first to the second cylinder, which if it could only be dealt with in a suitable receiver or larger exhaust pipe and broken up by something in the form of a boiler flue with cross tubes, through which the high pressure steam might pass, they would no doubt obtain considerable gain from it.

If they had 50lbs. more pressure in the jacket than in the cylinder, they would get beneficial results from it. He had occasion a few years ago to indicate an engine where they had jacketed cylinders but never used them. In using the low pressure jacket he found the amount of heat discharged into the condenser was 12½% less than it was without using the jacket. That was a consideration. They were sometimes told it was not safe to jacket large cylinders with high pressures.

If in 1900 they were not able to make a cylinder sufficiently strong to resist the higher pressures it was time they could.

He was no believer in 400 or 500lbs. pressures, 200lbs. to 250lbs. was quite sufficient if properly utilised, which he did not believe it was at present.

They found great variations in the ratios of cylinders for the same pressures. There was room for experiment to prove what was the best ratios at different pressures.

Mr. Robson had referred to a test which showed a saving of only ½lb., between 170 and 250lbs. pressure. The question therefore arose as to whether it was worth the extra expense required in making engines and boilers; as when they got beyond a certain pressure, in boilers, the price went up rapidly. He thought 200lbs. a good, satisfactory and economical pressure, if the engine, &c., was only properly attended to, and the best means adopted for utilising the pressure.

Great loss often arose through not keeping a thing warm when they had once made it warm. Sufficient attention was not paid to the boiler coverings, flange coverings, doors, the draining of steam pipes or water separators, &c. These might only be considered matters of detail, but they effected the economy of the plant.

When the great difference between the initial pressure in the high pressure cylinder and the boiler pressure, which existed in a large number of both compound and multiple cylinder engines, due to small and tortuous steam pipes and passages, they could not be surprised at the poor results obtained by some practically new engines.

Also when multiple cylinder engines were put down to drive a certain load, and when the full load was on the mean pressure in the low pressure cylinder (which in many cases was a very large one) was only six to eight pounds, how was it possible to expect economy from such an engine?

The only remedy for these defects was (in his opinion) to be found by the purchaser exacting a guarantee from the maker that the steam consumption per IHP per hour shall not exceed a fixed amount, to be stated when the engine was ordered, the amount of which can be arrived at from many high-class engines, from which was being obtained almost the best possible results according to the pressure used.

Mr. Saxon, in responding to the discussion, said that he was pleased that the paper had evoked a good discussion, and although he would not be able to reply to all the points the various speakers had raised, at any rate he would then take the opportunity of thanking them all. In the first place, with regard to the President's opening remarks, in which he asked for an explanation about dispensing with valves when they got beyond the high pressure cylinder. He would say that such an engine had been made and was being erected, all the parts having been made, in which valves were dispensed with, the pistons in the intermediate and low pressure cylinders acted for the inlet and outlet of the steam. It was not his own patent, and he dared not say anything about it yet; if it was a success he might give a description of it some future time, but if it proved a failure it would be buried in oblivion.

In reference to Mr. Ingram's remarks, he might say that he was quite aware there was little risk in giving a retrospect, but when he decided to write this paper dealing with the future development of the steam engine, he was aware that he was treading on debateable ground; but he still felt quite justified in the remarks he had made as to the future, particularly with regard to the boiler being the limiting factor in the case in the use of higher steam pressures and not the engine. The gain in economy, he considered, was not small, and while it would always be well to look for some other source of power, he would

not look for it in the way suggested by Mr. Ingram, which seemed delightfully vague.

Referring to Mr. Parry's comment on the small rise in temperature to be obtained with a considerable increase in pressure, he would say, that increasing the temperature of the steam, either by superheating or by a direct increase of boiler pressure, would be advantageous, and would tend towards making allowance for initial condensation, which was one of the principal sources of loss in the steam engine. As to high pressures not being consistent with high speeds, he felt quite sure that the evidence available went to prove that high pressures were quite consistent with high speeds. He would also point out that in connection with the tabulating of the strengths of materials based upon destructive tests, that factors of safety were adopted which were intended to make full allowance for the stress under which the article would live. It was however necessary to continue testing and revising our data.

He thanked Dr. Nicolson for agreeing with the paper to a large extent, but more particularly for the contribution he had made with regard to his experiments on steam leakage.

Mr. Robson's references to boiler design and balancing of engines were very opportune, and were worthy of consideration.

Mr. Mellanby did not think that great pressures would necessarily be economical and cited a case in support of his view. This was not a fair test at all he would submit, because engine cylinders could not be suitably proportioned for a load at 170lbs. pressure, and at the same time give the best results at 270lbs. pressure; it was very satisfactory that under the circumstances that even a small gain was apparent. A case had recently come under his own notice where an actual loss had been incurred in raising the boiler pressure from 90lbs. to 110lbs. without altering the engine, but this could not be attributed to the fact that higher pressures were not more

economical, but that the particular engines were not suitably arranged for utilizing the higher boiler pressure to the best advantage.

He thanked Mr. Ingham for his reference to his (Mr. Alfred Saxon's) father, and while Mr. Ingham did not go to the full extent indicated in the paper, still he expected development would continue. With his remarks on indicator diagrams he agreed.

Mr. Hillditch apparently agreed with superheating but he was afraid that the method he suggested would be too complicated.

Mr. Jos. Butterworth objected to the range of the paper, but seeing that the idea was to simply lay down the principal points of progress, he failed to see how it could have been treated differently, and as a matter of fact several points of progress were distinctly attacked and emphazised. He did not agree with his statement that three-quarters of the improvements available in the present engine would arise from keeping down the factor of surface volume to its lowest limit. The advice built on this theory as to the sizes of cylinders and the stroke in proportion to be adopted in future engine construction was not a very practical suggestion. He might say as a matter of fact, in cotton mill practice, that pretty much the same results were obtained from short stroke engines as from long stroke engines.

Mr. Hartley's remarks were very practical, and on the whole he agreed with them.

Mr. Henry Webb, in a communication wrote: With the first part of this paper we are all in accord, but when the writer ventures into the region of prophecy he lays himself open for criticism. There is an old adage which says "you should never prophecy unless you know," but I think Mr. Saxon is justified

in reasoning from the facts of the past as to the probabilities of the future.

There are several points that one would like to speak upon, but I do not think it fair for any one member to traverse the whole paper, so I will only touch upon two points. Mr. Saxon forecasts that for electric lighting and traction the engines will be made on the same lines as before, with modifications as the result of experience, such as larger units of power, increased pressure, better expansion, and improved lubrication. The present method of generating electricity, all will admit, is very wasteful. The units of heat in the coal by the use of a boiler are applied to water, and changed into steam. This steam is converted into mechanical energy, which is then changed into electrical force. At each of these operations there is waste, and it seems that there should be some other means of collecting and applying the electricity which we are told exists all around us in unlimited quantity. This seems to be a subject for special research.

The science of electrical chemistry is in its infancy, and it may be along these lines that the problem will be solved. I know a young man who is a chemist and anxious to engage in research in electrical chemistry, but could not find a college in England with a professor teaching this science, and has had to go to Switzerland to study the subject. If this is so it is a reflection on our country. Mr. Saxon's forecast is correct for the present, but may be upset any day by a discovery as startling as it will be useful.

A reference is made to the Glasgow engines, and Mr. Saxon thinks such are "well up to the producing capacity of the machine tools of stationary engineering works." I presume he refers particularly to the crankshaft. This shaft in its finished state weighs 82 tons, its main neck is 32in. diameter and 5ft. 11in. long, the webs are 8ft. 4in. long, and 6ft. 0in. wide at

the bottom end, and 15in. thick, with the crank pins forged solid.

There are at least seven firms in this country who can forge and finish such a shaft, and larger if required, and there are several marine engineers who could finish them. And if the demand comes the machine makers will be pleased to supply tools to any stationary engine maker to cope with even larger sizes, but I agree with Mr. Saxon in the units he names.

THE TOOL ROOM.

For the Manufacturer. For the Engineer.

READ SATURDAY, 24TH MARCH, 1900,

BY

Mr. Walter Heap,

(MANCHESTER).

I have felt for some time that the usefulness of a tool room in both engineers' and machinists' works has not been fully realised or understood. Therefore, I decided to give my ideas to this Association as to what a tool room should be, and how it should be worked.

Several attempts have been made during the past eighteen months to bring forward the advantages of the tool room, and questions have been asked relative to this subject on evenings set apart for topical questions, which have, I fear, resulted in no permanent good; sufficient interest not having been aroused to bring the subject home to members of this Association.

What I am about to give you this evening is what a tool room, in my opinion, ought to be; at the conclusion of the paper I hope to hear from members present whether they agree with me, and also for them to supplement my ideas with theirs, with the result that sufficient interest, I hope, will be aroused to make the tool room a very popular department in all engineering, tool-making and machinists' works.

If members will give their opinions on the subject it will greatly enhance the value of this evening's work.

The tool room suitable for a works where repetition work greatly prevails is unsuitable and too costly for a works where

the work is ever changing. I have, therefore, decided, to make the paper more useful, to divide it into two parts :—

(*a*) THE TOOL ROOM FOR THE MANUFACTURER ;

(*b*) THE TOOL ROOM FOR THE ENGINEER.

THE TOOL ROOM FOR THE MANUFACTURER.

The tool room for the manufacturer will be the larger of the two, and should be equipped with a good sliding, surfacing and screw-cutting lathe, not less than 6in. centres, 5ft. gap bed, fitted with a taper turning attachment, universal grinder, surface grinder, cutter grinder, universal milling machine, shaping machine, radial drilling machine, sensitive drill, tool grinder, twist drill grinder, and gas heating furnace—any of the foregoing may be duplicated to suit the demands of the works. With these tools you would make all special taps, reamers, cutters, jigs, mandrills, &c.

I do not advocate the making of standard taps, cutters, reamers and mandrels in the tool room, as I believe these can be bought much cheaper and better from makers who have specially laid themselves out for manufacturing these articles in large quantities.

The tool room should contain racks and pigeon holes for storing all the cutters, twist drills, flat drills, turning and planing tools, taps, stocks and dies, wrenches, hand drilling tackle, boring bars and cutters, templates, in fact all the loose tools used in the shop. Racks should also be provided for shop drawings.

A few words as to shop drawings I think will not be out of place here. I recommend one sheet for each piece, mounted on strong millboard, the size of which should be one-fourth of double elephant drawing paper. Each drawing to have a number as well as a title, this number being the number of the piece which it represents, and at the bottom left hand corner

the operations to be given through which the piece has to pass, in proper order, so that each man knows where the job goes next, thus keeping the work moving to its final operation. This saves a lot of time. It will be obvious to you that the millboards upon which the drawings or blue prints are mounted, being all one size, there will be no difficulty in keeping them in order, and any one drawing can easily be picked out when required.

Several sets of all kinds of hand tools and tools for the machines should be kept in the tool room to prevent waiting, which means loss to the firm. The keeping of the men and machines going soon pays for the extra outlay in these tools.

Having got the tool room thus equipped with tools you require really good men to work it. The foreman must be a first rate mechanic, able to design special tools and jigs. He should have a draughtsman in his office in the tool room, to make drawings of jigs, &c., as they are required. The workmen should be smart men, the pick of the works, and men who will take a deep interest in their work; such men are to be found who will do this, but their pay will have to be higher than that of an ordinary man. You will require an intelligent clerk with a boy to assist him, and this boy will get his first impressions of good work and make him all the better a workman when he goes into the shop. A labourer for inside and one for outside will be required. The duty of the outside man is to go round to all machines to collect tools which require re-grinding, and to replace these by others which have been re-ground. In my opinion no man on repetition work should be allowed to re-grind his own tools.

All the tools stored in this department must be kept ready for earning money. As soon as the tools are returned they should be prepared for work again immediately. All gauges and templates and jigs should be examined when returned to see if

they have sustained any damage, and if damaged in any way they should be put right at once, ready for the time when they will be required again. This examination brings home any damage to the man in whose hands the damage has taken place, and also has the effect of making the men more careful of the tools with which they work. All jigs should be kept in the tool room and be examined when returned after being used, and any damage made good.

From the examples about to be given it will be seen how I would work the tool room with reference to the various departments. A miller has say 500 castings to mill, this being the first operation. The piece number is given to him, and the foreman sends a labourer to the tool room with an order for the drawing, jigs, cutters and gauges for each milling operation on the piece, which are booked to the miller who is going to do the work. These jigs, cutters and gauges being in perfect order the work proceeds at once, and comes out all right and to size.

After milling, probably drilling will be the next operation—this will be seen from the operation list on drawing—the unfinished work is then forwarded to the drilling department. The milling jigs, &c., will be returned to the tool room, examined and got ready for the next lot. The labourer in the drilling department is sent by his foreman for the drilling jigs and drills required. The drills will be sent out in duplicate to prevent loss of time in re-grinding. In this way the work will proceed quickly and smoothly to the finish.

A system of this sort is requisite in repetition work, and this being so it is absolutely necessary to have a tool room properly equipped and managed.

In a manufacturing works I would allow no loose tools with the machines, further than those which actually belong to the machines.

It is of very little importance what system is adopted for keeping an account of the tools sent out of the tool room so that it is efficient.

Brass checks bearing the workman's number may be used and placed in the rack from which the tools have been taken. The foreman's order, previously referred to, may be placed in the rack or an entry could be made in a book kept for the purpose. Any alteration or improvement which can be made in jigs and gauges should be made by the tool room foreman, the manufacturing foreman being consulted as to the advisability of such alteration. In this way a very high efficiency in the output and quality of work may be attained.

In a manufacturing works without a tool room it is anyone's job to make tools, and they are generally, in such a case, made in a very indifferent manner with varying degrees of accuracy, and are never well kept; but where a tool room exists every tool is made in the most suitable form, with the greatest care, and kept up to proper working order, with the result that everything manufactured may be duplicated at any time. Again, the work of assembling or erecting is greatly reduced, in fact the machine goes together with little or no fitting, thus reducing the actual cost of manufacturing, a reduction which more than balances the cost of tool room, besides the satisfaction of knowing you can replace any part of the machine without having to fit it to its place.

When once you have a tool room going, you feel that everything is being kept up to the mark, both as regards the quality and the quantity of work, and the plant may be worked to its fullest capacity.

With reference to tool room cost-keeping, the foreman should issue orders signed by the work's manager. These orders should be suitably ruled to show what time and material has been put upon the job, with the money value of same.

The men whose duty it is to re-grind cutters, drills and tools, should book their time to each separate gang of cutters—to grinding drills—to grinding turning and planing tools, &c. This will give the cost of re-grinding for each separate department in the works. It will also be a means of finding out whether the quality of tool steel is being kept up in the works, and whether the materials being worked are as they should be.

The tool room should be placed in the most central position of the works, and be accessible from two sides, if in a large room.

I have not given any statistics or examples of tool rooms in existence. Perhaps there are members present who can give one or the other from tool rooms already existing, and if this is done freely the object—in part—of this paper will have been accomplished. Then there remains the influence it will have upon manufacturers to establish tool rooms in their works, and to those who have already done so, it may suggest improvements. It is my opinion, gentlemen, that unless we adopt means for keeping our tools up to the highest standard of perfection we shall be left behind, and the only way of doing this is by having a well equipped and well managed tool room.

THE TOOL ROOM FOR THE GENERAL ENGINEER.

This tool room will not be equipped with the machinery found in that of the manufucturers, whose work is ever the same. The general engineer does not have that amount of repetition work which would pay him to make jigs and keep such a large stock of gauges, cutters and reamers. It is more of a store-room for loose tools than a tool room, fitted with racks, pigeon holes, &c., for the reception of tools and drawings. A fitter's bench, vice, surface-plate of medium size,

tool grinder, small cutter grinder, and an ordinary grindstone or wet emery wheel; I think these will about meet the requirements. When new boring bars, boring heads, and other tools used in a general engineers shop require making, the machine tools in the shop would be used, and any fitting required would be done by the tool stores fitter. It should also contain a set of standard cylindrical gauges, the range to cover the general work done in the shop, these gauges to be kept for reference only, other gauges made in the shop should be used for general use. A standard steel rule, say 4ft. long, would be found very useful; also a 12in. vernier to obtain correct measurements of odd sizes not included in the range of cylindrical gauges. A hardened steel 18in. standard square should not be omitted.

A large assortment of twist drills can be bought of all sizes rising by $\frac{1}{64}$in., there is no necessity for using common drills for the odd sizes. I would suggest that no drills be kept at the drilling machines, when not in use they should be returned to the tool stores. The man in charge would regrind and put them in their own racks. This man should be an intelligent mechanic, a good all round man with a youth to assist him. Such a man would know when the tools were returned, whether they were in a fit condition for use when required again, and would always keep them sharp and in a good condition for work.

All flat drills must be kept in the stores. These drills should be properly made and kept up to size—no going to the smith's shop to have them flattened out, and no grinding down from one size to another should be allowed by the turner, whose lathe is standing idle while all this is going on, besides having drills all shapes and sizes. It is quite as necessary to have standard flat drills, turned and properly filled up, as it is to have standard twist drills. The foreman turner will have to see

that each lathe is provided with a good substantial drill rest, which when fixed in the slide rest will be the right height without having to put packings under. This will give you good holes and they will be the right size.

Sets of turning and planing tools made out of various sections of steel, suitable for the lathes and machines should be kept in the stores always ground and ready for work; these to be supplied to the workmen and returned to the stores when the cutting edge is gone and others given to him.

To prevent the machine men leaving their machines a labourer should be appointed to act as tool carrier; this man would be continually going round to all the machines collecting tools for repairs and re-grinding. I would suggest that a sample tool be kept in the tool stores of each kind of tool in use. A sample would be required for each section of the steel from which the tools are made, these samples or patterns to be sent to the smith that he may forge new tools and repair old ones correctly. The adoption of this system would result in a great saving, the machine tools would be kept almost continually running and doing work. The man would have no excuse for going to his neighbour for the supposed purpose of borrowing tools when he really is going to have a chat about the merits of some race horse or football player. I daresay some of you have had such an experience.

The tools would always be in the best condition for earning money, and the tool stores would become a great source of profit. Work would be done more accurately. A good supply of bolts and cramps should be kept in the tool stores for use on the machines, each length and diameter of bolt being kept in separate racks, instead of each machine being supplied with an assortment all tumbled together under the machine or in a box (a most common practice), many of which are almost useless, the threads being in such a condition that when the final

screwing up takes place the nut strips the thread and another bolt has to be hunted up. Don't have a cheap man or labourer only in the tool stores; it is false economy; have, as I have already said, "a good all-round mechanic" who knows when tools, &c., are in good working condition, and see that he does his duty; let him be fully responsible for the proper up-keep of all loose tools, your men will very soon get used to this sort of thing and will soon see that it is to their advantage to support this system.

Good steel mandrels, hardened and ground, should be kept in the tool stores. The initial cost of hardened and ground mandrels is a little high but it is true economy, they last much longer and truer work is obtained by using them. I would advise engineers to buy them whenever the standard sizes kept in stock will suit their requirements. When it is necessary to make mandrels make them out of cast steel, have the ends turned down and hardened, finishing them after hardening, see that the centre tools are good. I would never make a mandrel out of iron or mild steel; don't have makeshift mandrels, they are very costly. A stock of cast iron bushes to drive on small mandrels for larger holes will be found very useful.

Planed cast iron parallel packings should be kept in the tool stores.

With regard to hand screwing tackle have the best obtainable, see that the tap wrenches fit the squares on the taps, this will reduce the breakage.

The man in the tool stores will have instructions not to allow any tool to go out unless it is in a good and fit condition for its work.

I believe that the success of any business depends greatly upon the attention paid to small details. The small details in your equipment require a lot of attention, and the tool room

properly managed is a department for watching over and caring for these details, and it is an easy thing to do when a man has been appointed for this purpose. Let your men feel that you take an interest in these details and they will help you. The result will be a better class of workmen, better work, and more of it.

DISCUSSION.

The PRESIDENT (Mr. Henry Hodgson) said no doubt a tool room was a most useful adjunct to all works, but unfortunately many of them believed in it without having acquired one. Some of their shops were built yesterday, and others the day before yesterday, and were perhaps not cut out for the tool room system. Still he thought it would be advisable for engineers to pay more attention to this question. The engineers of this country had a battle to fight, and unless they paid more attention to details they would lose ground in it. He should also like to know Mr. Heap's opinion on the question of the tool holder system as against forged tools.

Mr. E. G. CONSTANTINE said most of them would be prepared to admit that it was the proper thing for other people to have a tool room, but when it came to establishing one themselves it was a different matter. There could hardly be two opinions as to the necessity for a proper system of dealing with tools, and the jigs, and various other accessions required for the successful and economical working of machine tools.

In the abstract a tool room was undoubtedly a proper thing to have, and if he were establishing a works to-morrow, it was one of the essentials to which he would pay most attention.

Mr. JOHN J. ROYLE said it appeared to him that in a tool room everything depended on the man in charge. He must be

something more than a good mechanic; he must be a sort of genius, with something of an inventive and constructive faculty, common sense, and knowledge of the connection between means and end.

He thought it was not necessary to demonstrate that every engineering establishment ought to have a tool room of some sort, that tools should not be lying about all over the place, but he had always thought that if they put down a fully equipped tool room there was a possibility of its not only attaining the end for which it was started, but also "running to seed," and as it were "eating its head off." They would have to so arrange it as to secure all the advantages without any "running to seed." One difficulty connected with this was to keep the man or men in the tool room properly employed. It seemed to him that part of their time could be so employed not only in keeping up tools, but in making new ones, even twist drills, reamers, &c.

Speaking generally, it behoved engineers to pay more attention to this important subject, as it lay at the foundation of orderliness, neatness, and commercial success.

Mr. W. Yates said he was connected with a works containing about two dozen machine tools, and he should like to know how a tool room would serve for a small works of that kind.

Mr. C. W. Hunt said that a short time back he was at a small works where there were less than two dozen tools, and probably not more than that number of men. They had, however, a small tool room in the gallery running round the shop. This room was pretty much on the plan suggested by the author, and the manager told him that for one or two hours per day, or one day per week, according to requirements, one of his best fitters went up to the tool room and ground all the twist drills and reamers, and got up all the taps, dies, &c., keeping

them in proper order. The time boy was in the habit of running round the shop and kept generally in communication with the men, and fetched and carried the tools as required, no man ever having to stop his machine to grind or sharpen his tools. There was a small hand hoist from the room below to the gallery. This tool room was one of efficiency and economy, and had proved a great saving to the firm.

Mr. James Saxon said no doubt many of them, if they were starting fresh works, would make immediate provision for a tool room if they had the requisite capital, but being established already on a certain plan, with men accustomed to that plan, it would take them a long time to alter their basis of working in existing establishments, as such an alteration was bound to be brought about gradually. In works of that kind the men generally had the tools they were using at the machine and in connection with it. If they each had a tool room it would not be all gain. If a driller was drilling some holes, and the changes, as in the case of their works, were very great, he would have to be travelling backwards and forwards, or a labourer on his behalf, to the tool room, for the various sizes of drills he required. Mr. Royle had mentioned one thing, of which they were afraid, *i.e.*, that if they established a tool room on a large scale its costliness would be such that it would run to seed, and become too great a standing charge upon the production.

It was, of course, very much easier to start a tool room in a new works, where they could educate the workmen to it as they came in, but it was much more difficult where they tried to upset old arrangements, such as existed at their own works. It had already been shown in the discussion that in some works the workmen had resented its introduction. He believed however they were all aiming at a good tool room, and hoped to

arrive at it some day. Some of their friends had already embarked on it. Messrs. B. & S. Massey, neighbours of theirs, had a tool room, where they were carrying out pretty much the same system as indicated by the author. Most of them had established what was, in one sense, equivalent to a tool room—standard tools were kept in stores to which the workmen had to go when they wanted them, and where their condition would be noted.

Mr. S. Boswell thought it possible for the system to be carried too far. Taking a district where every shop had a tool room, what good would men be who were trained in that district when they went to another district where the same system did not prevail.

It would in more ways than one relieve the men of responsibility. Many a good tool was destroyed not through its own weakness but through bad handling. If it were sent to a tool room the foreman might not be able to detect how it had gone wrong, but if the man were left to himself he would perhaps be more careful in future. He thought also a certain amount of time might be lost with the tool room system.

It was all right where standard tools and gauges were used, to keep them in proper condition, but when it came to carrying a man's chisel away, and grinding it for him, he thought they were going a little too far.

Where "catalogue" work was being done, and the various standard parts were made by the gross, placed on the shelf as it were ready for "assembling," the tool room no doubt had its advantages, but where "specification" work was in hand, and probably no two orders were alike in detail, it was doubtful whether the tool room was worth its cost.

Mr. Vose said one of the advantages of a tool room was that it acted as a spur to effort and invention on the part of those

who had charge of it, and these men would often be able to suggest improvements in the design of articles that could be carried out to advantage.

He was glad the author said a good word far the old, despised flat drill, which when kept in order had a very important place in a shop.

One or two firms now made a speciality of little stands, to go in different parts of a shop, so that the workman could easily lay his hands on the tools, bolts, &c., he required. A tool room could keep those stands supplied with bolts so that there would be no need for direct application to the tool room for bolts by the men requiring them.

Mr. J. Gunther said that at their works, which was neither a large nor a small one, they went in for a tool room directly after the Engineer's dispute. At first they started a tool room in which their twist drills, &c., were stored; after a few weeks' working this had to be extended, and they put down two twist drill grinders, new furnace, &c., and ultimately they put in lathes, grinding and turning tools, twist drills, milling cutters, &c. They found every advantage accruing from its use.

Before the strike they went on the usual Lancashire custom; each man had forged tools, and when he could not find a particular tool he went and took out a piece of steel and had it forged to his own ideas. In five weeks under the new system they cleared out something like three tons of forged tool steel, and replaced it by about half a ton of tool steel adapted to tool holders.

At the present time each leading man was furnished with a small range of tools, from six to nine in number, adapted to various sizes of tool holders. These were kept in one half of a box which was painted a different colour on each half, and in the other half the old tools were placed when their edge was worn off; a labourer went round and took the blunt tools to the

tool room, where they were examined by the tool fitter, sent upstairs to the gallery to be ground up and then put into stock. The result was they were using a minimum of tool steel; they had to have a certain number of forged tools, but even in the case of these they put them in the store room, and they could see at a glance what tools they had stored there. They made all their own jigs, &c. Standard cutters of course it was cheaper to buy, but other cutters they made themselves.

As regards cost, they had to make up their minds to a comparatively large initial expenditure. They found at their works that they had to make radical changes throughout, and those men who would not fall in with them had to go.

As to the cost of running, leaving out interest on expenditure and such like items, the wages bill was considerably less for the same amount of work, and practically the same for the greater amount of work they were now doing. If they were building a new works they would certainly adopt the same plan on a larger scale.

As to the advantages of the tool holder, where ever it was applicable—although it was not applicable in all cases—they found that it effected a considerable saving. Under the old conditions the men used to congregate round the grindstone, but they had none now. They used the Carborundum wheels now.

Mr. F. C. Forth said it would be interesting to know something as to the proper size of a tool room, its position, the number of hands to be employed there under average conditions, and the cost of the system.

Mr. R. Matthews said a good many works in this country had been carrying on tool rooms for a long while. Hawthorne's of Newcastle—where he served his time—had carried one on

for quite 30 years, and it had not "run to seed" yet, as suggested by one of the speakers.

As to tool holders, when he joined Mr. Goodfellow, and introduced piecework there, he gave the men the option of having tool holders or heavy tools, and without exception they all stuck to the tool holder where possible.

Any firm, however small, was bound to have a tool room if they wished for thoroughly successful work, and where the place was large a gauge room also was necessary. Accurate measurements should be reduced to as few men as possible, as similarity of touch and feeling amongst workmen was almost impossible.

He was a great advocate of tool holders in every case except where they really could not put a tool holder in. A good many of the old tool holders were wrongly designed, but better ones were made now. At their own place, working on oil-hardened steel up to about 48 tons breaking strength, they had often in a lathe no less than eight tool holders, taking up to 1¼in. cuts.

They put down a tool room three years ago; they had a gauge room already. They had a system of keeping gauges whereby these were booked down to the men, and any damage done to them could be traced to the man using them when they were returned to the store.

He could not imagine any works so small that they could not keep one man going in what might be called a tool room. Personally he supported the author from his own experience in every point he had urged. In a small works employing about 24 men, if they had a man in a tool room at £2. to £2. 10s. per week, that meant only £120. to £130. a year, and the saving effected by having a tool room would be a great deal more than that.

The PRESIDENT said he was at one time work's manager of a firm employing 800 hands. They determined to start a tool room, and it was set up between Saturday noon and Monday morning, without the men's knowledge, The men on turning up on the Monday morning, had to go to the tool room for their tools, but he wished to say that they experienced little or no difficulty in connection with the change, so far as the men were concerned. It proved a successful system, and they were enabled to clear out 10 tons of tool steel. It was a great saving in that respect. The tools were far better worked up and used.

Mr. HEAP said with regard to the difficulty of starting a tool room in old shops he thought they could not start it too early, if their shops were built 100 years ago.

As to the relative merits of tool holders and forged tools he thought it depended on the work in hand. He rather held with Mr. Webb that for very heavy material a good forged tool was the best, but for light goods a tool holder was the best, and he intended to adopt it as much as possible.

In a tool room they could grind solid tools as well as loose tools for holders.

He agreed with Mr. Royle that if a man in a tool room was not fully employed he should be put to make tools that would otherwise have to be bought, if he could do the work.

For small works a tool stores, with a good leading hand on the job, would meet the case.

With regard to the difficulty suggested by Mr. Boswell in the case of men removing from one district to another, that difficulty would not arise when the tool room system was adopted generally.

Mr. Gunther's remarks referred to a place where he, himself, had once been employed. They turned out good work then,

and he was sure they would turn out still better work now they had a tool room.

He had not had time to get up details such as those asked for by Mr. Forth.

The President's remarks showed that there was no difficulty with the workmen in starting a tool room.

He was going to a place on the 2nd April where they had no tool room, and before he undertook the job he stipulated that they should start a tool room. He gave them figures as to the probable cost and obtained their consent to the change. He expected they would save plenty of money by it.

TOPICAL QUESTIONS.

MEETING, SATURDAY, MARCH 10th, 1900.

Question 1.

"Has steel used in the tool holder any advantage over a solid forged tool?"

Mr. S. Dixon said his firm used a tool-holder system, and he could speak as to its advantages. One advantage was that they could use a small section of steel, and there was no necessity for forging which involved a deterioration in quality owing to the constant heating and drawing out of the steel. By using a small section of steel they could have a higher quality, whilst by having one uniform section they could arrange for one man to grind for a whole workshop, and tools could be ground and kept in stock. This would prevent the necessity of men going backwards and forwards to the grindstone, which led to great waste of time in talking amongst the men, and also to a loss owing to the men stopping the machines whilst they went to the grindstone. The man at a machine could also keep a full supply of tools by him, and these were supplied by the man who did the labour, so that there was no necessity for the man at the machine to go to the tool room or the grindstone, and the machine was thus always kept going. By using a small section of steel they could use up a greater proportion of the steel, whereas in forged tools scarcely more than one-fourth of the steel used originally in the forging was used in cutting. Then there was a great advantage in being able to use a higher quality of steel. They paid a rather high rate for the higher quality of steel used in the tool-holder, but if they tested tools

made of the common tool steel against steel of a higher quality they would find a great difference between them, and that the latter would last much longer without grinding or changing. The objection made against the tool-holder was that there was not a sufficient mass of metal to carry away the heat, but he thought they would find that over-heating did not actually take place. It was only the first quarter of an inch at the point of a tool that ever got really over-heated, and if they investigated the matter they would find there was no more tendency to over-heating in a tool-holder than in a solid tool, and that no difficulty arose in this respect.

Mr. Henry Webb said they had tried all sorts of tool-holders, and had to throw them into the scrap heap. They found nothing so suitable as a good solid tool about 2¼in. square. They had to turn steel forgings, and to reduce the the diameter about 1¼in. at the first cut over, and found that fancy tool-holders, with a high quality of steel, were not half rigid enough, whilst they became so hot that they were no good at all. For roughing a high carbon steel they required something better than a flimsy tool-holder.

Mr. Dixon said solid tools were spoiled by heating and being continually pulled out of the fire. This need never come about if they had a proper gas furnace where they could just heat the tool enough and no more, but of course if they had not proper apparatus that was another question. As to using a better quality of steel, they used Mushat's—at more than 1/- per lb. As to men wasting time by congregating round a grindstone, Mr. Dixon was right, but the same argument applied to solid tools as well. If they had a proper tool room could they not have solid tools ground there just the same? As to the man having a full supply of tools by him, could he not be kept fully supplied with solid tools just as well?

Mr. Vose thought a good deal might be said on both sides of the question, and both systems could be used in a shop with advantage. With the tool-holder system it was even more essential that the tools should be machine ground or systematically ground than it was with solid tools, because, being of such small size they were difficult for the ordinary workman to hold. In every shop both systems should work "hand in hand," and the best results could be got out of both if the tools were ground by machinery. As to the want of rigidity in a tool-holder this could be obviated by putting a little screwjack underneath the tool where needed, and it would be practically as good as a solid tool.

Mr. Z. Tetlow said Mr. Ford Smith read a paper before the Institute of Mechanical Engineers in 1886, in Manchester, in which he gave facts and figures showing that there was a saving in the smithy and grinding department of over £150 a year, whilst although they dropped the price of piece work to the men they made more money than before, after they had adopted the tool-holder system at his works (Smith & Coventry).

A Member said he had a tool in a tool-holder that had been working three weeks, reducing 1½in. bright drawn steel to ⅝in., and had never been ground yet.

Question 2.

"Is anything known of the driving power of the various kinds of belts in general use?"

Mr. A. Rea, in introducing the subject, said that he must claim the indulgence of the meeting as to doing more than merely giving the barest outlines of the question, owing to the time at his disposal which was only sufficient for introductory purposes, the different topics from their variety and interest being fit matter for a special paper.

At the same time he would endeavour to give a brief synopsis as to the relative power or driving force of a few well-known kinds of belting. In dealing with this subject however, from a general point of view, it must be clearly understood that in actual practice a great many circumstances and conditions have to be taken into account when making a comparison of the efficiency obtained from various drives.

These may be summarised as follows, viz :—

(*a*) The relative diameters of the driving and driven pulleys to each other and so on.

(*b*) The distance of the shaft centres apart and the angle at which they are placed in the site.

(*c*) The condition in which the belts are kept as to adhesiveness, etc., to suit the case.

(*d*) The effects of unbalanced pulleys, excessive crowning, with the shafts not in perfect alignment to each other.

All the above affect materially the driving force of belt gearing unless due provision and allowance is made in connection therewith as to the power required to be transmitted.

At all events it is an unwritten law that the primary agent in belt driving is friction. It follows therefore that for efficiency of transmission the belting employed should be of such a nature that the co-efficient of friction between its surface and that of the pulleys upon which it runs should be sufficiently high to insure a good frictional grip of the pulley being obtained without requiring the belt to be unduly tight.

Probably a greater loss of power is traceable to the employment of unnecessarily tight belts than to any other cause. It is a natural sequence therefore that any excess of belt tension over and above that necessary to prevent slipping when starting under the load is a direct waste of energy.

The chief qualities to be aimed at in high-class belting which may be recognised as of prime importance are:—

Flexibility and adhesiveness to give frictional grip, strength and lightness to ensure lasting qualities, especially in high speeds, and prevent undue sagging between the journals, evenness of construction so as to give uniformity when running, etc.

The fact therefore cannot be too strongly emphasised, that badly designed belt gearing is a perpetual source of loss and annoyance involving as it does waste of power in transmission with many other kindred evils. This being so he had much pleasure in placing a few tests before them of driving belts, which in all probability may lead to somewhat greater interest in the subject, these having been made by Mr. Charles Hopkinson, M.I.C.E., M.I.M.E., B.Sc.

TABLE IA.

Comparison of Driving Belts, 3in. wide, running 1,353 feet per min.

Description of belt	Link leather	Leather cemented and sewn, best quality		Camel brand belt
Authority	Statement quoted by Prof. Unwin	Unwin Machine Design P·383	D. K. Clark's Tables	Reddaway Tables
Safe Load I.H.P.	6	4·79	6	8·72

TABLE Ia.—*Continued.*

Hopkinson's Experiments, Fixed Centres.

Total initial tension	Link leather		Leather		Camel brand	
	I.H.P.	Slip per cent loss of power and speed	I.H.P.	Slip per cent loss of power and speed	I.H.P.	Slip per cent loss of power and speed
457lb.=76lb. per inch width of belt of slack and tight parts. Initial arcs of contact 180°	8·4	1·65	..	..	..	..
	10·43	1·95	..	..	..	..
	12·54	2·65	12·83	2·1	12·75	1·0
	14·6	3·16	..	..	14·08	1·15
	..	..	15·09	3·0	15·8	1·26
	..	..	16·24	3·4	16·69	1·48
	..	..	..	..	18·65	1·9
	..	..	..	..	19·66	2·4
=793lb. .. .. (per inch of width)	..	..	12·66	1·3	12·59	0·8
	16·65	2·05	16·81	2·1	16·73	1·15
	20·82	2·56	20·82	3·6	20·75	1·4
=132lb. .. .. (per inch of width)	22·94	3·16	..	..	22·67	1·48
	23·9	3·5	..	..	..	..
	..	..	..	..	25·62	1·75
	..	..	..	..	28·5	2·35
	..	..	..	..	30·4	3·0

REMARKS.—With less total tension than 475lb., the linked leather belt would not drive steadily.

With an initial tension of 76lb. per inch, the linked leather belt drove 2·43 times the working load given by the authority quoted, the plain leather drove 2·71 times, and the Camel brand 2·25 times, so that with a not excessive tension, the Camel brand, when driving 1·45 times the load of a leather belt, has nearly the same margin of spare strength and adhesiveness.

With the initial tension of 132lb. per inch of width, which is very high for a leather belt, the leather belts showed less inferiority relatively to the Camel brand belts.

TABLE Ib.

Comparisons of Driving Powers of Belts 6in. wide, running 1,353 feet per min.

Description of belt	Link leather belt	Leather, best quality		Camel brand
Authority	Statement quoted by Prof. Unwin	Unwin Machine Design P·383	D. K. Clark's Tables	Reddaway's Tables
Safe load I.H.P.	12	9·58	12	16·75

Hopkinson's Experiments.

Total initial tension	Link leather		Leather		Camel brand	
	I.H.P.	Slip per cent loss of power and speed	I.H.P.	Slip per cent loss of power and speed	I.H.P.	Slip per cent loss of power and speed
121lb.=10·08lbs. per inch width of belt slack and tight parts	Would	not drive	Would	not drive	16·73	1·46
lb. lb. 233=19·4 do.	..	..	do.	do.	..	..
345=28·75 do.	Would	not drive	14·69	3·7	..	..
457=38·08 do.	19·8	2·66	..	..	30·44	1·81
793=64·41 do.	23·73	4·18	32·68	2·94	36·82	1·84
1,129=94.08 do. Arc 197°	36·24	3·5	40·43	2·77	47·07	2·27

Table II gives the results obtained so far in the ratio of tensions in the tight and slack belts with the 3in. belts as above, and similar belts 6in. wide.

TABLE IIA.

Brake free to move with the stretch of the belt.

Total tension in tight and slack constant for each record. Maximum ratios of the tight to the slack belt with corresponding loss of power and speed from slip on creep.

The arcs of contact were estimated by inspection, and where not noted specially varied from 180° to 192°.

Total amount of tension in slack and tight belts	Link leather belt 3in.			Plain leather belt. 3in.			Camel brand belt 3in.		
Lbs.	I.H.P.	Ratio	Slip	I.H.P.	Ratio	Slip	I.H.P.	Ratio	Slip
345	..	..	..	10·58	6·92	2·1	10·53	6·85	1·4
401	..	..	..	..	..	..	11·48	5·65	1·3
457	..	..	..	14·74	8·4	8·85	15·6	10·9	2·5
569	17·92	7·62	2·86	..	..	..	..	..	..
	..	9·74	B	18·33	8·3	2 64	19·9	12·2	2·1
681	20·87	6 92	1·14	20·54	6·56	2·56	24·56	15·6	2·7
793	23·0	5·84	2·57	23·53	6·2	2·73	25·83	8·72	1·9

B.—Signifies that the belt ceased to drive the brake and slipped on one of the pulleys.

TABLE IIB.

Total tension in slack and tight belts	Link leather belt 6in.			Plain leather belt 6in.			Camel brand belt 6in.		
Lbs.	I.H.P.	Ratio	Slip	I.H.P	Ratio	Slip	I.H.P.	Ratio	Slip
457	12·3	4·91	B	15·09	8·85	3·4	17·2	23·7	1·33
	Belt	New		Arc 215°					
	17·7	35·5	2·5	16-25	14·2	7·6	17·46	27·5	2·35
569	17·8	7·4	0·6	..	..	..	20·67	16·5	2·7
	20·42	15·0	2·5	..	..	..	..	..	..
681	16·66	4·0	7·4B	..	..	..	25·8	25·78	2·18
	23·42	11·27	2·45B	..	..	..	25·7	22·5	1·7
	Belt pasted and run between these determinations								
793	26·73	10·25	5·9	24·76	7·4	2·6	29·24	19·1	2·0
		Arc	210°	25·68	8·5	3·0	..	..	..
905	29·03	8·37	3·1	..	..	..	32·47	15·0	2·0
		Arc	205°						
	..	10·24	B	..	..	..	34·85	31·9	2·0
1,017	30·18	6·24	3·2	..	..	..	33·7	9·4	1·7
		Arc	205°						
1,129	30·75	4·95	2·6	36·65	8·61	2.44	35·67	8·1	1·7
		Arc	190°	..	..	..	41·0	16·5	2·0
	32·53	5·7	3·0	..	..	..	42·11	21·11	B
								Arc 187°	

REMARKS.—The powers for all the determinations given in Table IIA, were transmitted by a 10in. Camel brand belt with an arc of contact of about 170° on a 22in. pulley, the belt speed being 820ft. per min., the maximum useful tension for the tested belts being 210lb. by the 3in. Camel brand belt. The remarks also apply to Table IIB.

The relatively superior results of the 3in. belts as compared with the 6in. belts in the first series are probably due to the greater effect of the "crowning" of the pulleys upon a wide than a narrow belt.

In reference to the various driving belts at present manufactured, he regretted, as stated, that he was unable to do more than mention a few of them.

May belting, which is celebrated for its great strength, flexibility, lightness, grip or driving force. A belt $\frac{5}{16}$in. thick being quite equal to a double leather belt $\frac{1}{2}$in. in thickness, the breaking strain of an ordinary 5in. woven May being given as equalling 12,051lbs. This belting when kept in good condition with some belt paste and painted outside occasionally with a little castor or boiled oil, gave out most efficient results; in fact this latter applied to belting generally, the driving face when kept clammy preventing slip.

Belata belting, which could be joined together in one continuous length, without fasteners, and from the special material used in its manufacture was exceptionally adhesive and flexible, requiring no paste or other ingredient to keep it in condition, and though probably not suitable for all circumstances and conditions where there was excessive moisture from oil or other causes, at the same time for general purposes the makers claimed that with a moderate tension there was practically no slip arising from the particular nature of the belt.

Woven leather belting, which could also be made continuous to suit each case, without fasteners, gave very satisfactory results. Being somewhat new however he was not in a position for the moment to give any tests of its efficiency; at all events it is turned out as an open challenge to any existing form of belting for strength, durability, lightness, equality of stretch, grip, and cheapness.

With regard however to ordinary leather belting, it must be admitted that for special drives, where there is considerable reversing of the belts, such as planing and other machines of a similar kind, leather belts stand unrivalled for durability and efficiency.

It is also claimed for a particular brand of leather belt called Orange Tan that it is

45 % stronger than oak tanned leather,
25 % ,, ,, helvetia ,,
45 % lighter per ft. run than oak tanned,
30 % less stretch,

with greater flexibility and adhesiveness.

Then there is the question of leather and other covered pulleys, and having made numerous tests and experiments in connection therewith as to their driving force he found that leather belts, on leather covered pulleys, working flesh side to flesh side gave 50 % more efficiency, other beltings 30 % to 40 %. Paper mache covered pulleys 20 %. Carpet covered pulleys 20 %, and so on, no covering however equals leather flesh side out. Where the ratios of pulleys therefore are somewhat unusual it is always advisable to cover at least the smaller pulleys so as to increase the driving force.

In conclusion, however, he ought to state that it was a common error with many users of belting to make the face of the pulleys narrow in order to economise on the first cost of same, but this false economy seldom decreased the cost of the machinery, and only saved a trifle in the first cost of belting.

The small amount saved was soon lost by the stopping of machinery, caused by the slipping of belts, strain on the shafting, increased friction, requiring additional driving powers, and destruction of the belts themselves.

Were pulleys made a proper size and width of face, and then covered with leather, having belts of proper width rim arranged

as described, a considerable saving of coal could be effected annually, and an immense amount of trouble and annoyance avoided.

Mr. S. Boswell said he had had some experience in the testing of belts. He had tested leather, and found there was "leather and leather." Then there were a great many different classes of woven belts, canvas belts, cotton belts, so called camel-hair belts, &c. In testing leather he found that it would do all its stretching long before it got to its maximum load, and would break at its maximum load suddenly, so that if there were a 3ft. leather belt in, from the engine to the top storey of a cotton mill, it would almost pull the place down if it broke. As to the flexible woven and canvas belts, when they began to destroy them they would stretch and stretch until they could be pulled in two with the hands, never breaking suddenly. He also found that belts, such as those made of canvas which were saturated in syrup, gave better results in the testing machine than "dry belts." The latter seemed to cut each other in the fibres, while those saturated seemed as though the fibres were lubricated.

Generally the woven belts seemed to stretch more evenly and break over a considerable area, rather than square and short across, and it appeared to him that cost for cost the leather belt was "not in it." So far as strength for strength was concerned, taking a 4in. four-ply woven belt, it would carry a load better than two thicknesses of leather in a 4in. belt.

As to the flexible belts he had found two brands superior to the others; he was not however prepared to give any free advertisements, but nearly all the manufactured belts were better than the leather belt so far as carrying the load was concerned, as shown in the testing machine.

Mr. Henry Webb said he had an expensive experience at a cotton mill in connection with woven belts. A woven belt was put on every mule in the mill. Now in duplex driving, where the belt had to be whizzed from one pulley to another, after so many seconds, the edges of the woven belts by the action of the strap forks wore away very quickly, and they had to put in leather again.

Dr. Nicolson said a certain Mr. Taylor made an experiment with regard to belts extending over seven or eight years. Mr. Taylor had an opportunity of fitting up one side of a workshop with belts in which he adhered to the ordinary practice as regards their width, and on the other he put belts in some cases twice as wide as would ordinarily be the practice. He kept strict account of all expenses in connection with the two sections, and found that owing to the diminution in the breaking down of belts, repairs, &c., the expensive belts, which were so much wider than anyone would ordinarily think of putting in, paid for themselves over and over again after seven or eight years working. The belts were of various kinds, but it seemed that it did not matter what the material was so long as the belts were far too wide for the work.

Question 3.

"What is the best method of testing lathes for accuracy?"

Dr. Nicolson said that in the new technical school they hoped to have examples of all the best appliances in mechanical engineering, and they wanted to lay themselves out for testing all kinds of machines and parts of machines. The question of how to test machine tools for accuracy was of course one of very great importance. There were other things however they would wish to test in a machine tool besides its accuracy. They had to consider the handiness of the machine for its work, and the

intelligence with which it was laid down in its place, to facilitate work; its durability and its efficiency as a power user. No doubt the accuracy of the tool covered the latter point to some extent, because if the lathe bed was made of the proper shape and strength, so as not to deflect, there would no doubt be less loss through friction.

He had made some experiments at the McGill University, Montreal, on this question, on lathes of American or Canadian types, much lighter in section than those made inEngland. The results therefore might not be applicable here, but at the technical school they hoped to test American and English lathes, and those made in other countries, and see whether there was any superiority in any of them. They hoped to get loans of machines from members of that institution to submit to tests, and they could give the resulting information to people who were interested in it.

The tests he had made were more in the direction of finding the efficiency of the machines as power users than their accuracy. They had a dynamometer fixed so as to measure the power received by the machine through its belt; then there was a hydraulic support—just a little circular casting with an india-rubber diaphragm laid across it. The diaphragm was bolted to a plate in the centre, and there was a little strut on which the tool rested so that the force received by the tool was transmitted to the disc and on to the diaphragm, which rested on a liquid, and this led away to a Bourdon gauge, so that the actual load the tool was subjected to was transmitted to the gauge, and they had a means of recording what the load was. They did this without any chatter owing to the hydraulic arrangement being such a dead support. The tool was guided between two well-fitting jigs, with the axes a long way back so that there was little friction on them. Another hydraulic support was fixed on the end of the lathe screw, so that the

push transmitted by the screw to the diaphragm of this support was also measured. The lathe was simply an ordinary one with two broad cast iron legs, and they tried the effect of supporting the legs differently, and putting a wedge on one leg and then on the other. They had two telescopes on the bed of the lathe resting on three screws, one on one bed and two on the other, one at each end, and looking through the telescope on to a rough scale on the wall, when nothing was going on, they could tell what the twist was. The deflection, they found, was inappreciable. He thought the design of lathe beds might be looked into in this respect as they were usually designed to resist deflection as a beam, but he found their chief liability was to twist. They had a spindle driven by a dog and a friction brake at the other end to put force on equal to what the tool would put on, and they drove the lathe with this friction grip on the end of it and resting on the bed, so that there was a twisting force on the bed just as if they were driving and they found a very considerable amount of deflection at one side, between $\frac{1}{100}$ and $\frac{1}{200}$ of an inch and they also found that the lathe screw required about twice as much power to drive the saddle along as it did when that was not so. He did not like to suggest anything serious on this question, but it had occurred to him as a result of his experiments that they ought rather to make the bed of the lathe simply a circular cylinder, coming up and supporting the weights, or something of that kind which would be more suitable for resisting twisting than a couple of H section beams which were more suitable for resisting deflection. The latter was not nearly so serious a matter as that of twisting.

He would be glad of any information respecting the testing of lathes or other machine tools.

Mr. R. Matthews said the amount of power required for driving a lathe was very small comparatively. As to the

distortion of the bed this was what was generally expected rather than deflection. Generally Whitworth's had erred on the right side by putting in so much cast iron in their beds, with an ample number of cross ties, that the distortion was inappreciable. That was a very interesting suggestion about hydraulic supports for tools, but he rather doubted its accuracy. He did not see how they could get a hydraulic cylinder supporting a tool altogether free from vibration.

Dr. Nicolson said they did not get it absolutely free from vibration. There was a little shake but no serious amount. The indications presented practically a straight line all along, whereas with other means of testing, with springs, &c., they showed great "freaks."

Mr. Matthews continuing said it was much more important to get accuracy than to test the power for driving a lathe. Accuracy was the great thing to aim at, but nowadays very few people would not pay for it.

Mr. S. Dixon said there was often great carelessness in laying down lathes and other machines. Anyone setting down lathe beds ought to know that these big cast iron beds were flexible and this fact must be remembered in setting them down, or twisting would take place. A firm to whom they had supplied a planing machine made great complaints about it, and on going to see what was the matter, they found that the machine had been simply dropped down on a concrete bed and screwed down with foundation bolts, and they had succeeded in twisting it $\frac{1}{16}$in. By setting it with a spirit level and adjusting the bolts up till it came level, the machine was found to be perfectly true.

It would be a good thing to give a written description as to the proper way of putting down of machine beds. This point

was very important. One firm had a lathe which they managed to twist by putting it down improperly, and then they said it was out of truth. When they came to look at it they found the firm had been filing away on the side of the bed for a fortnight trying to get it right, but were no nearer, in fact it was getting worse; they had simply ruined it, and it required two or three weeks to get it back to the condition that had been destroyed. Extreme care should be taken to put machines down thoroughly level, to avoid twisting, which led to great trouble.

Mr. J. Parry said it came to a question of supporting lathes at three points instead of four. People would twist them and they should therefore give them fewer points to twist them on.

Mr. Vose said it was very peculiar how accurately Manchester workmen could work without knowing what they were working at, as it were. The "paper" method seemed to be thoroughly understood by them, and they never seemed to bother about $\frac{1}{250}$in., or $\frac{1}{1000}$in., &c., but it seemed to be thoroughly understood that the paper method was accurate enough.

In American papers he had seen descriptions of various ways of testing. For instance they got the alignment of the loose headstock spindle by means of a micrometer.

We did not seem to have any general way of testing here and it seemed an interesting point as to why some more definite method did not come into general use, but he was surprised at the accurate results obtained by "working to papers."

Mr. Wenk said he had seen a micrometer adjusted to different parts of a lathe, and the latter tested by the micrometer screw. He had seen them test the head of a lathe as to whether the centre was true or not; and also whether other parts were true

or not. A lathe could certainly be tested properly by means of a micrometer screw.

Mr. Thompson said a lathe might slide in the shaft perfectly true, and when they came to bore a hole this would be quite taper. Workmen in many cases did not seem to understand the setting of the fast headstock and would adjust it from one end to make it slide straight, and the lathe would bore a taper hole. What they wanted to do was to get the fast headstock absolutely true with the lathe bed and then move it bodily into position to slide straight. Then they would get a straight hole.

Mr. Dixon said the geometry of the thing needed to be considered. The fast headstock spindle must be perfectly parallel with the bed, so that when they were boring a hole from the carriage it would be perfectly parallel. Then the loose headstock spindle must be true with the fast headstock spindle, and this could be tested by trammelling. The loose headstock spindle must be perfectly alignable with the fast headstock spindle, but they must trammel it in various positions, not merely in one. For accurate sliding the centres of the fast and loose headstock spindles must be perfectly alignable with the bed. For surfacing they could test by trammelling.

The "paper" method was well established amongst workmen. With fine tissue paper they obtained a great degree of accuracy. A skilled workman in time obtained a delicate touch by this system and could work with paper more accurately than by any measurements of thousandths of an inch, &c.

45TH DISCUSSION SESSION.

OPENING MEETING,

OCTOBER 13TH, 1900.

DISCUSSION.

PARIS EXHIBITION, 1900;

ITS LESSONS AND SUGGESTIONS FOR ENGINEERS.

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SECTION I.

Metallurgy - - - Mr. Henry Webb.

GENTLEMEN,

The President has asked me to speak on this subject. What I have to say must necessarily be brief and somewhat "scrappy," and I must ask your kind indulgence for any omissions. My time at the Exhibition was short, only one week, and there was so much to see, and naturally I had to give attention to other things besides metallurgy, especially to engineering and machine exhibits, &c. Consequently I have had to supplement my own observations by comparing notes with friends, and also by the report of Prof. H. Bauerman to the Iron and Steel Institute.

It should be remembered the idea of the Exhibition is to show the progress of the world for the last 100 years. The

exhibits of metallurgy for the most part occupy the north end of the east part of the twin building in the Champ de Mars. But, with the exception of the French exhibits, I thought there was no systematic arrangement; they were scattered here, there, everywhere, many of them difficult to find; and in some instances the objects are placed in special buildings in various parts of the ground.

Ores.—The present condition of the ore mining industry in France is well illustrated by the collection of maps, sections, bore holes for the various districts, and specimens of ore from all the districts are shown, and their analyses given. The total production of ore in France is about five million tons per annum. Considerable difficulties have been experienced in opening deep mines owing to the large quantity of water encountered in sinking, which, in some instances, has led to the adoption of the Poetsch system of freezing the water-bearing strata around the sides of the shaft. A small representative specimen of British ores has been sent by the Home Office, and the Canadian Dominion has sent some good samples.

Coal, Coke —The foregoing remarks on ore apply also to coal and coke as to maps, sections, methods of working, and samples of the products of the various districts are shown and the analyses given.

Bricks.—Sand, clays, cements, bricks, paving slabs, &c., of all kinds are shown, as used in blast furnaces for smelting the ore, and in the open hearth furnaces for making steel, as well as bricks made from the slag. In all cases the chemical analysis is given, and in most the mechanical tests.

Furnaces for smelting the ores, are represented by drawings. Several views and full details of the newest blast furnaces in France are given, and the Carnegie Co., of Pittsburgh, U.S., send blue prints of one of their largest furnaces.

Pig Iron.—Samples from all the districts are exhibited, made from ores of varying richness, iron made from ores smelted with coal, with coke, and with charcoal. They are all classified according to numbers and uses for forge, foundry, or steel making. The chemical analysis of each is given. The production of pig iron in France is 2,576,000 tons per annum.

Alloys.—To steel makers especially the exhibits of alloys must be interesting and instructive. Samples of Chromium, nickel, manganese, silicon, vamadium, titanium, uranium, boron, tungsten, cobalt, aluminium, molybdenum, are shown. Specimens of steel containing both chromium and nickel are shown, ranging, according to hardness, between 41 and 48 tons in tensile strength, with 19 to 23 % elongation, and a 26 % nickel steel giving 46·5 tons, with 65 % elongation on a length of 4 inches. Schneider & Co. show a full-size model of the 150 ton nickel ingot for a large forging. There are many examples of nickel steel forgings in many parts of the exhibition, showing this material is extensively used.

Under this head of alloys I would call your attention to several objects of great metallurgical interest in the German section, illustrating Dr. H. Goldschmidt's method of reducing the oxides of chromium, nickel, manganese, and other refractory metals, by combustion with finely divided aluminium. An application of his method is used in the welding of tubes or rails by the intense heat developed in the reduction of a mixture of oxide of iron and aluminium and other substances, supplied as a mixture called "thermite."

For a full description of this process I would refer you to the paper read by Mr. Lange to the Iron and Steel Institute in Paris, entitled "A new method of producing high temperatures."

In my opinion this new process is destined to play an important part in metallurgical operations, and may eventually unfold a source of heat of incalculable benefit to the human race.

Iron and Steel.—This is the largest section, and the exhibits in the French section are particularly fine, and includes iron and steel work for uses in military, naval, and railway services, and is supplemented by a large show of ordnance and armour plates in the naval and military buildings in the Quai d' Orsay. You can see heavy castings, forgings for artillery, forgings of all kinds and shapes, single, double and treble-throw cranks for marine and stationary engines, shot and shell, tested loco. and wagon tyres, plates and sheets of all sizes, many flanged and wrought into various shapes. Strips of all widths and lengths, rails and other sectional iron of all conceivable shapes (one exhibit has 550 sections of the products of their rolling mills shown in a glazed cabinet). A difficult section to roll is some heavy flanged forms of tram rails, weighing up to 105lbs. per yard, with a groove in the head 1⅜in. deep, and very thin web and flange. There are tubes of all diameters and lengths, both solid drawn, and welded.

Many of the exhibits are most artistically grouped, forming large trophies, requiring great skill both in design and execution. "One trophy consists largely of pressed work, such as furnace plates, steam domes, manhole covers and other boiler fittings, forming a tall arch, a fitting entrance to the metallurgical section from the main door of the palace." Another firm has "applied the higher geometry to decorative purposes, by constructing a paraboloid as a trophy, in which the ruled lines defining the surface are made of bars, rails, angles, and other sections of steel, the geometric axis being represented by an inclined and vertical frame made of plates and joists, the latter being crowned by an open framework studded with polished railway buffers." Again a maker of pit tubing for collieries, &c., has arranged a complete ring of tubing, 23ft. in diameter, as an arch over one of the main passages. Another is a tall trophy built of curved and straight joists, resembling a church steeple.

There are several large trophies made of tubes of steel, or copper, or brass. There are many large stands filled with sections of iron and steel, most skilfully arranged and with excellent effect; showing the tensile strain, ductility, and other capabilities of their products. They are twisted into all conceivable shapes, flattened, bent cold, punched in every direction, split, jumped up or drawn out, all showing a marvellous quality. (Of course the failures are not shown.)

To particularise is difficult. In forgings there is a hollow steel shaft for a battleship, forged on a mandril, 76ft. 8in. long, weight 36½ tons, by Schneider & Co., and is a grand piece of work. In rolling there are plates, 57ft. long by 8ft. 2in. wide, ½in. thick, strips 7in. wide, 0·12in. thick, and 213ft. long, strips 19in. wide, 0·2in. thick, and 115ft. long, flat bars 302ft. long, and some very long rails.

In flanging and press work there is a fine piece of work in the Russian section, namely, a sphere 9ft. diameter. In the German section a boiler front with two holes for furnace tubes, and a boss for the water gauge pressed at one heat. In the French section the trophies aforenamed.

Steel Castings.—The largest is a stern frame, rudder post, and outer brackets (for a transatlantic steamer), weighing 80 tons (in four parts). There are large magnet rings, screw blades, engine beds, roll pinions, and several very difficult turbine castings. I noticed a cast iron melting pot weighing 9½ tons.

Solid Drawn and Welded Pipes of every description are shown in large quantities for gas, water and drainage purposes; a special feature being the Rogé method of strengthening cast iron pipes by steel hoops put on hot. This has been applied to a main 39in. diameter and five miles long, and to others 49in. and 60in. diameter.

One of the largest examples of welded work is a gas reservoir made of steel plates ½in. thick, 59in. diameter, 65ft. 7½in. long, with ¾in. ends, weight 27,000lbs., and tested to 248lbs. per square inch, all welded by water-gas blow pipe flames.

Aluminium.—Pure aluminium and its alloys in ingots, bars, plates, and other rolled forms, castings and a series of manufactured objects are shown by several firms. One firm shows an application of aluminium in the place of copper for conveying a heavy electric current, and in these days of great demand for this purpose it should become a formidable rival to copper. Many show very fine castings, some quite large, and the covers for tram motors seem to be generally made from this metal. Others show frames for automobiles and other carriages; these must be made from an alloy. In the Military Pavilion is a portable aluminium military bridge; this is a lattice truss girder of a span of 57ft., with three beams each in two pieces, weight 18 cwts. for the metal work and 12 cwts. for the wooden platform, and will carry a 46 cwt. military wagon with 6 horses and 40 men passing at the double.

Copper, Tin, and alloys of these metals I had no time to examine.

SUMMARY.

The French section, as may naturally be expected, excels in the number, largeness, and variety of their exhibits in metallurgy. *Germany* sends little bearing on the production of iron and steel, their display being in mining and metallurgical machinery, tools, &c., and the same may be said of *Belgium*. *Italy* has a large exhibit from the Terni Steel Works, and there are also specimens of the ores. *Sweden* has a well arranged series of exhibits, contributed by most of the well known firms, showing wrought iron for steel converting purposes, as well as cast steel of the highest class. *Austria and Hungary* have some very fine exhibits of pig iron, iron and steel, a variety of

castings, as well as machinery. *United States* are scantily represented considering their large production, but there are some fine exhibits of open hearth and crucible steel. There is in this section a very fine display of wire (one small bundle being 37 miles long). The draw plates and dies for producing bright bars of many sections are also shown. *Russia:* The exhibits of this country show most remarkable progress, they have large and handsome exhibits brought together from all parts of European Russia and the Ural. Ore, iron and steel, and their finished products, castings of all descriptions, copper, chains, tubes, armour plate, &c., &c. *Great Britain:* the representation of the metallurgy of this country is very small. Messrs. W. Jessop & Co. have the best position, and send a varied collection of objects in cast steel, ribbon steel, blister and cast tool steel, &c. The Farnley Iron Co. contribute tests to show the special qualities of best Yorkshire iron. There are a few other exhibits, chiefly from Yorkshire.

The large exhibit of Messrs. Vickers, Sons & Maxim is contained in a separate building, and fully maintains the reputation of this country. The British Aluminium Co. make a notable display of their products.

The most interesting novelty in the Exhibition is in the American Section at Vincenne, and is a new method of treatment of steel cutting tools invented by Messrs. F. W. Taylor and Maunsel White employees of the Bethlehem Steel Company.

The exhibit shows a lathe in actual operation turning steel in a practical way with cutting speeds fully two to three times faster than ever before used.

Three grades of steel are turned off in the lathe, with a standard depth of cut and feed. A depth of cut of $\frac{3}{16}$ inch and feed of $\frac{1}{16}$ inch has been selected as a standard cut, as it represents about the average of general practice. Three grades

of steel—soft, medium hard and very hard, have been selected as best suited to show the range of adaptability of the tools to all classes of work.

With this standard cut the soft steel is turned off at a speed of a 150 feet per minute, the medium hard steel at a speed of 60 feet per minute, and the very hard steel at a speed of 15 feet per minute.

These results are obtained with tools made by a newly invented process which imparts to the steel of which they are made the property of cutting at a very high working heat, that is, a tool retains a hard cutting edge when heated to a visible red heat. This phenomenon alone makes the exhibit one of a very remarkable character, showing and explaining the possibility of the attainment of a very high practical cutting speeds.

The importance of the process to all users of metal cutting tools may readily be seen, and the time and cost that may be saved in performing regular shop work easily computed.

On work wanted with the least possible delay, such as repair work, &c., a saving in time may be effected by the use of these tools, with a consequent saving in expense that can hardly be overestimated.

Tools made by this process have been in practical use in the three machine shops of the Bethlehem Steel Company for a little over a year. The principal shop of this Company, which is the largest machine shop in the world, being more than one-fourth of a mile in length, contains many small tools of various kinds and a number of the largest lathes, planers and slotters in the world. A large proportion of the work consists of guns, armour, marine shafting, etc., much of which is nickel steel making the average tensile strength of the material from 100,000 to 110,000 lbs. per square inch, which is a much harder material to machine than is met with in the majority of shops.

The gain which has been effected by the use of these tools is shown by the following results, which are the average of all tools in the shop.

Average cutting speed per minute increased from 9 feet to 25 feet. Average depth of cut increased from ·23 inch to ·30 inch. Average feed increased from ·07 inch to ·087 inch. Average pounds of metal removed per hour per tool increased from 31·18 to 137·3, showing a gain in actual work of 340 per cent.

In the Paris Exhibition the metallurgical exhibits are numerous and varied and well worth careful study, and reveal that other nations can do quite as well as ourselves, and will become increasingly keen competitors in the markets of the world.

SECTION II.

Stationary Engines - - Mr. Alfred Saxon.

Mr. President and Fellow Members,

The duty of describing, as far as the limited time will permit, the Stationary Engines exhibited at the Paris Exhibition, has devolved upon me.

These engines are for running purposes, chiefly arranged for Generating Electricity, one or two examples for Mill Driving being exhibited but not working, so that Electricity has dominated this section of the Exhibition almost absolutely.

Time will not permit of going beyond the category allotted to me, or it would be interesting to refer to the 1,000HP Gas Engine, the Steam Turbine Engines of the Parson's and De Laval types, Blowing Engines, Rolling Mill Engines, and also Marine Engines, which were exhibited. The Exhibition may fairly be said to be the largest, most comprehensive, and cosmopolitan in the Stationary Engine class ever brought together, and to give the members who have not had an opportunity of visiting the Exhibition an idea of the variety and extent of the exhibits, I may say that France alone, in engines of 300HP and upwards, is represented by approximately 20,000 IHP; Germany comes next with 10,000 IHP, followed by Austria with 5,000 IHP, and Switzerland next with about 4,660 IHP; England only holds fifth place in importance in the size and extent of its exhibit with 4,230 IHP; then follows Belgium 3,200 IHP, Italy 2,000 IHP, Holland 600 IHP, and Russia bringing up the rear with a pair of engines developing 350 HP. America is not represented directly, but the Societé Française de Constructions Mécaniques exhibit a 3,000 IHP engine of the Cross Compound Vertical Type, made to the designs of E. P. Allis, of Milwaukee, United States, which I have included in the French Exhibit.

The grand total of the horse power of the exhibits of the various countries mentioned amounts approximately to 50,000 IHP, which can be divided between the two principal types of Stationary Engines—Horizontal, and Vertical: the Vertical Type accounts for about 16,500 HP and the Horizontal Type about 33,500HP—twice as much.

The three largest engines exhibited are of the Vertical Type, each capable of developing 3,000 IHP, the well known Willans type high speed engine representing England; France and America are represented by the E. P. Allis Cross Compound Vertical Engine already mentioned, whilst Germany's reputation is sustained by the Borsig Engine, which is a Tandem Four Cylinder Triple, with power passing through two cranks.

The largest engines of the Horizontal Type are three of 2,000 IHP each, two being representative of French Practice, by a Lille firm, one of the two pairs being a Cross Compound arranged for Rope Driving, bnt not working, and the other a Pair of Tandem Four Cylinder Triple Expansion Engines for Electric Driving, with Corliss valves all placed on the bottom of cylinder; the other Engine, representing German Practice, with the Sulzer type of valves, was also a Tandem Four Cylinder Triple Expansion Engine.

Speaking generally of the engines, they included all well known types: Single Cylinder, Compound, Triple, and one or two cases of Quadruple Expansion, an Italian firm exhibiting a Quadruple Expansion engine, developing 800 HP, of the Vertical Type with cylinders arranged Tandem fashion, the power being transmitted through two cranks.

Engines of the Single Cylinder Type of large size were met with only in the French section, and although we should consider them to be a wasteful type and very much behind the times, still they are working generating electricity; one of these

engines is capable of developing 1,200 IHP, and two others 1,000 HP each.

If time permitted, the arrangement of the cylinders of the various Types would be interesting to refer to, but I must pass on to notice the effect of the development of Electricity and its influence on the Steam Engine.

The first point is that in the Direct Generation of Electricity from Generators placed on the Crank Shaft, the number of revolutions in all types of engines has been considerably increased, with the result of the enclosing, or partial enclosing, of the principal moving parts. One of the most striking features in the Horizontal Type is the introduction of elaborate circular splash guards round the cranks and connecting rod ends. The influence of Speed has also caused the lubrication of the various parts of both Horizontal and Vertical engines to receive very considerable attention, and is also to be noticed in the valves, and the gear for working same many ingenious arrangements being exhibited, but the type of valve and gear mostly in evidence is that of the well known "Sulzer" type, which works excellently and noiselessly at high speeds. It is exhibited by Swiss, German, French, Austrian Belgian, Italian and Russian firms, and also by an English firm for the admission valves only. This would seem to be the most cosmopolitan type of valve in the whole of the exhibition. The valve next in popularity to the Sulzer is the Corliss; in some cases a combination has been effected of the Sulzer and Corliss, but invariably the Sulzer is, I believe, in such cases used on the High Pressure, or Governing Cylinder, and the Corliss on the Low Pressure.

One noticeable feature is the limited use of the Piston Valve and the almost universal discarding of the Slide Valve. Speaking of Valves and Valve Gear, it is interesting to observe that in the Belgian exhibits, which consist of three engines of

the Horizontal Type, one of the firms exhibited the Sulzer Type of Valve, another the Corliss Type, and the third the Piston Valve.

The engines generally were well and accurately finished, with one or two noticeable exceptions; most of them were arranged with the Cylinders and Covers steam jacketted, and to work with Super-heated Steam. Many of the engines are fitted with Electrical Barring Arrangement. Great attention has been paid to detail: the lagging of cylinders, splash guards, drippers, lubricating arrangements, painting, hand-railing, floor-plates, staging, and all accessories are, as a rule, finished in a most workmanlike and even artistic manner; great taste has been displayed throughout by those responsible for the production. If I had to come to a decision as to the engine which pleased me most, I should select one representing Belgium, although Switzerland is undoubtedly close up; perhaps the most striking exhibit was that of Germany, as represented in the Borsig Engine.

And now, Mr. President, having outlined what struck me as the leading points in the exhibits, I wish to deduce the lessons to be learnt from them.

The first thought that struck me is that English engineers are not behind-hand in the principles and ideas connected with Steam Engine Practice, but that we do not pay sufficient attention to details and to finish, and that artistic design is very much lacking in our productions.

We must recognise more than we have done that the development of Electricity must gradually displace our present arrangements of gearing, and be prepared to adapt ourselves to this new condition of things. High speeds are inevitable, and better design and workmanship will be absolutely necessary.

Further, Technical Education is necessary for the Employer as well as for the Employee: the Foreigner, generally speaking,

is better educated, more artistic, and consequently appreciates to the fullest extent the influence that perfection in detail has upon the complete machine.

English engineers may with advantage take up the Sulzer Valve and Gear: Steam Jacketting and Superheating are worthy of more attention.

More expensive engines, which the Continental Type of engines seem to be, will be sought after by our customers, especially if the high price of fuel is maintained. We must not hesitate to copy the best designs of any country if we cannot design anything better of an original character ourselves.

In conclusion I would say that English engineers must obtain more capital for the development of their business, and at any rate, those who carry on an Export Trade must be to the front in the Exhibitions of the world. No doubt it will be urged that English Governments do not give the encouragement to our exhibitors that other Governments do to theirs, but for all that the English Engineer must not consider himself too busy or be too indifferent to enter into healthy competition with Foreign Engineers for the Markets of the World.

SECTION III.

Machine Tools - - - Mr. Samuel Dixon.

DEAR MR. PRESIDENT,

I much regret that I cannot be at the meeting to-night, but have pleasure in offering a few observations as requested on the machine tools exhibited, but as the time allotted is very short these must of necessity be brief.

In no branch of engineering do I think there is a more general or international display than in that of machine tools, for not only are there typical exhibits from France, Germany, England and America, but also from Austria, Switzerland, Sweden and Italy, and even from Russia. Compared with the two previous exhibitions at Paris, one is first struck with the very great advance made in every country (particularly in the last ten years) both in the design and construction of machine tools, for although there are yet many evidences of crude design exhibited, yet, on the other hand, there are many excellent examples of good design. Another prominent feature is the seemingly high quality of the workmanship throughout almost all the leading exhibits, and one cannot but admire the excellent taste displayed by many continental workmen, particularly in the finish of details; but whether the machines also possess all those highly essential qualities of accuracy, as distinct from mere polish and finish, it was impossible to determine from inspection.

There was ample evidence however that high mechanical skill is not the monopoly of any one firm, or of any one country. There was also much greater evidence of the true application of sound workmanship to strict utilitarian purposes (*i.e.*) where really necessary, and a remarkable diminution of those displays merely for the purposes of ornament. Again there is an absence

of that attempt formerly made by some firms to show evidence of extreme refinement, in some parts of machine construction, where it was quite unnecessary. One then saw the racks and pinions of planing machines made by one large firm in tool steel, with all teeth cut out of the solid by end milling cutters, as in slot drilling, leaving flanges on both sides of both racks and pinions, and even going so far as to harden these and grind every tooth—the whole at a prodigious cost.

The question of the relative sizes of machines exhibited is only a secondary one, depending often on circumstances beyond the control of individual firms. The largest were undoubtedly in the French and German sections, mainly due to the fact that ample space had been allotted to the firms, and the machines were ultimately destined for one of the government arsenals, in fact ordered beforehand so that they would be exhibited.

It is extremely difficult to classify machine tools on a strictly scientific basis, but the great family easily subdivides itself into two great sections. 1st, machines for general engineering workshops, each designed to take a variety of work, and 2nd, special machine tools designed for specific purposes, among which we may put the automatic machines, though these take numerous objects of similar design.

Among general machine tools there was a somewhat remarkable absence of planing machines, though the rapid supersession of most planing operations by the milling machine doubtless accounts for this, yet of those exhibited, not excepting the American, there was not one at all equal to the best English planers, though unfortunately there was not an English one exhibited. Those exhibited were lacking in some of those elements of solidity and essential design for sound heavy cutting. There were good English examples of the overhung side planer, but I was surprised to find that the strange freak known I think as

an open side planer, and which I first saw in America in 1890, had been taken up by a German firm, and a fairly large size shown. This is very like an ordinary planer with the offside upright removed, leaving the cross slide projecting and carried by one end on the front upright. The work reciprocates as in an ordinary planer, but when a broad object is put on the table the overhanging part is supported (as I saw it in America) by a roller running on a rail on the floor. The quality of the work from such a device can be easily understood, but one cannot imagine anyone buying such a machine.

In slotting machines there was nothing new, and among shaping machines on one large American stand there was an amusing copy of a Whitworth shaping machine, not as made to-day, but as made and illustrated 30 years ago. The copy was not merely in quick return motion but in details down, even to the ratchet palls with triangular bosses and springs. I can only regret that in this section there was not a good English shaping machine exhibited.

As regards boring machines there was one fine machine for boring and milling large engine cylinders up to 6ft. or 7ft. diameter, and similar work. This had all motions driven by independent electric motors, and was elaborated to such a high degree that it would require a very highly skilled man to understand even the machine itself let alone the work.

In respect to drilling machines there were many evidences of improvements, particularly among radials.

Among light engineers' lathes there was strong evidence of the influence of American design, for where there is only very light cutting these light lathes suit the light-built Frenchman admirably, but where there is heavy cutting to be done the English lathes of the highest class (not the merchants' article) have nothing to fear in the rivalry of the German or American types, and though gibbed carriages and beds, for a generation

the established practice in England, are now claimed as novelties in American construction.

Of the great modern family of milling machines, not only for light manufacturing purposes but also for heavy engineering work, there were many good examples, and strong evidence of the development of milling, lending itself as it does with great advantage to the machining of objects formerly done on planing, slotting and shaping machines.

Among the milling machines for light manufacturing purposes the Americans shewed to advantage, but in heavy machines for general engineering work the best examples were undoubtedly to be found in the English, German and French sections. In some cases it would seem as if the designer had only considered the geometrical question of revolving the cutter and reaching to desired positions, but the far greater question of stability of cutter, when a heavy cut comes upon it in any of these positions, had often been neglected or only indifferently provided for. The increasing practice of cutting the teeth of most wheels led to many automatic machines being exhibited for cutting both spur, scroll and bevil wheels; the most original machine for cutting bevils, in which both sides of a tooth are operated upon, hailed from Salford. French constructors have a remarkable preference for helical teeth in wheels, and it is carried so far as to make even many bevil wheels with helical teeth, and though the advantage is I think of little or no moment, yet it has led to the exercise of much ingenuity to accomplish same.

In boring and turning mills there was an extensive display in the French, English and American sections, showing the popularity of the machine for certain purposes. In screwing machines for bolts and tubes, where the display was mostly between the English and American sections, I think all engineers will agree that the English more than hold their lead. In steam hammers I must not omit to say that I consider

our English makers were well in front, and made a good display.

Among the truly automatic machines, as distinct from machines with usual self-acting motions, there was a fine display; and here again, strange as it may seem, in a field which was once claimed as peculiarly American, the best machines for engineering work were of English construction.

It is curious what an amount of clap trap appears in the daily press about automatic machines, and even in some engineering journals where special knowledge might be expected. The blessed word "Mesapotamia" was never in the running compared with the word "Automatic" as one to conjure with, for we find it used just as if machines existed (of course in America) into which it was only necessary to feed pig iron and steel bars and then by setting an index plate we could get marine engines, locomotives, or dynamos turned out ready for delivery, one man minding ten machines.

In their true position as machines for producing small screws, studs and pins, in fact the "smallwares" of engineering construction, they are of great value where large quantities are required, but where small quantities and varying designs are required, as in very many engineering works, the established English design of universal capstan lathe exhibited well holds its own.

There were also several prominent examples of the special lathes, introduced in recent years, for boring and turning cast iron parts, such as cylinder covers and similar forms, by the use of broad cutting tools mounted in a capstan rest. With soft American cast iron this method is in many cases quite practicable, but with the comparatively hard metals of Europe the results seemed far from satisfactory, for although the surface was fairly machined, yet the object would require mounting again and further finishing before being sent for polishing.

Some of the lathes for this purpose were also exceedingly complicated and even clumsy, and any attempt to work them with unskilled or low-class labour would have most disastrous results in breakages; in fact no one but a very highly skilled man could be set to work them.

There was one fine automatic machine for turning and boring small castings, which were fed into a hopper, these being chucked, bored, turned and cast off automatically and completely finished. The irregularities of castings however soon set a limit to the application of entirely automatic machines, even the inequalities of round bars for the automatic screw-making machines play havoc with them, and render cold drawn bars a necessity.

As connected with machine tools I would mention the remarkable exhibit of tool steel by the American Bethlehem Company, which allows of stiff steel forgings being turned at a cutting speed of 140ft. per minute, or seven times quicker than the present rate. This will doubtless have a considerable influence on the construction of machine tools in the near future.

Of the great family of special machine tools, such as are so largely made by leading English firms, there were but few examples, as such machines are not suitable for exhibitions.

Reviewing the Exhibition as a whole, it is evident that the important part which machine tools play in the productive capacity of a nation is becoming much more generally recognized, and engineers are becoming more alive to the necessity of putting down only the very best.

The very best does not of necessity mean the most elaborate machines, for among many machines exhibited this elaboration of mechanism has been carried to an inordinate degree, many being extremely complex though wonderful studies in mechanism. There is evidence I think of a reaction against this elaboration

and attempt to make each machine do everything, and the best established English and European practice of having most machines specially designed for the particular manufacture is coming into more general favour, and its importance appreciated.

In the future I think that English makers will continue to have the strong German competition to meet in European and even Colonial markets, even more than in the past and more than that of any other country, not excepting America, but of the Englishman's capacity to hold his own I have not the slightest doubt.

SECTION IV.

Textile Machinery - - Mr. Joseph Nasmith.

The exhibits of textile machinery demonstrate that even in this, which has been looked upon as a specially British industry, there is a growing competition, the Continental exhibits being greater in extent than those of British origin. There is unmistakable evidence in the design of many of the machines from the Continent, of their British origin, some being practically copies of the latter. On the other hand there are also signs of original thought, and it would appear that the stage had been reached when mere imitation was giving way to experiment and research. At any rate with one exception there is little to be seen in the British exhibits which is novel, although the show of Messrs. Platt Bros. & Co. Ltd., fully maintains the reputation of the firm, and together with the exhibit of Messrs. Brooks & Doxey Ltd. demonstrates that in cotton machinery at least this district is still *facile princeps*. It will be better to devote the time at disposal in dealing only with the novelties exhibited in order to show the progress made.

At the stand of Messrs. Brooks & Doxey there was shown a spinning frame invented by Messrs. Ashworth & Gaunt, Fig. 1,

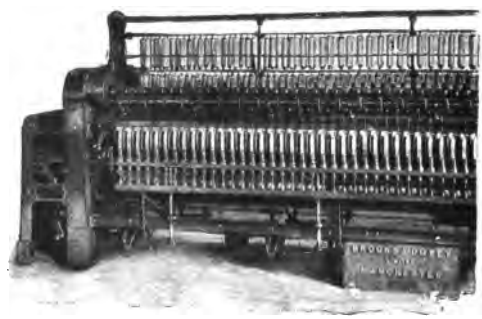


Fig. 1.

which is designed to spin yarn on the bare spindle in the form of a cop. This has been often attempted, but in the present

case with success. The following are the various conditions under which twisting and winding take place in the operation of cotton spinning. There is—

(1) The continuous twisting of the material by the rotation of a flyer, and its simultaneous winding by rigidly controlling the speed of the surface on which it is wound. This is the procedure adopted in the roving machines.

(2) The twisting of a certain length of the material by the rotation of a spindle and its winding as a subsequent operation. This is intermittent spinning as used in the mule.

(3) The continuous twisting of the material by the rotation of a spindle and its simultaneous winding by the retardation of an eye or clip revolving round a surface concentric with the spindle and surface on which it is wound. This is the principle of ring spinning.

(4) The continuous twisting of the material by the rotation of a flyer eye and its simultaneous winding by retarding the surface on which it is wound. This is the principle underlying throstle spinning.

The Ashworth frame is constructed according to the fourth class, which is the only type of machine which gives an approximately even twist to the yarn. It differs from the throstle frame inasmuch as it winds the yarn not on to a bobbin but a spindle, and lays it not in parallel layers but in successive conical layers as in the mule, forming, in short, a cop and not a bobbin.

The machine exhibited by Messrs. Brooks & Doxey, Ltd., contained 112 spindles of 2½in. gauge. The roller and drawing mechanisms are similar to those in the ring frame, which in appearance the machine generally resembles. The spindle is a "dead" one, tapered at its upper end, and is sustained by a footstep and bolster, which are respectively fixed in two rails. The footstep rail receiving reciprocal motion from the builder,

the upward motion being, like the ascent of a mule winding faller, slow, and the downward motion, like that of the faller, being rapid, so as to lay the binding threads.

The upper or bolster rail is fixed, and has secured it in the dish-shaped bolster, which is formed with a downwardly projecting shank, screwed for a certain distance so as to permit the bolster to be secured to the rail, like a ring spindle. Inside the dish of the bolster an upwardly projecting nipple or shell is formed, which, with the shank, is bored for the passage of the spindle. Below the screwed portion, half of the shank is cut away, for a purpose to be afterwards referred to. At the bottom of the bolster dish a washer is placed covering the whole of the bottom, and specially constructed to prevent the churning and "sudding" of the oil. Above this is dropped a cast iron washer on which the foot of the spinning cup or flyer rests. The whole of the bolster is filled with oil, and provision is made to ensure it lubricating the surfaces without permitting it to escape and overflow.

The spinning or twisting is effected by a carefully made cup or flyer, which has a downwardly projecting shank bored to pass over the nipple in the bolster, thus obtaining a bearing. The cup is also bored to permit the spindle to pass. It is formed above the shank with a warve by which it is driven from the two tin rollers, and around its upper edge is a narrow flange in which is the eye through which the yarn passes on its way to the spindle.

In order to wind properly allowance must be made for the difference in the tractive power of the yarn at different points of winding on the conical nose. Provision is made to ensure lightness of running of the spindle, and its resistance is regulated by an ingenious variable drag in the manner following:—

The shank of the bolster is cut away below the nut, this exposing the spindle at that point. To the shank is pivoted a light wire cradle, forked at its inner end, and carrying between

the fork a small flannel roller, which presses on the spindle. The tail end of the cradle is coupled to a short link chain, the other end of which is connected to the lifting motion in a manner which is not necessary to describe. The chain consists of a series of rows, each of which as they approach the cradle contain more links, so that the chain gradually gets heavier. When the spindle rail is raised so that winding is going on at the nose, the chain is raised, so that none of its weight or very little is on the wire cradle. As the rail descends so as to cause winding to take place at a higher point, the chain falls into a loop, gradually putting more weight on the cradle, until winding takes place on the shoulder, when it is at its maximum. The result is that the pressure of the flannel roller on the spindle is also greatest then, and the required retardation of the spindle is obtained. As winding goes on from the shoulder to the nose the weight is gradually taken off, and the pressure decreases as the winding diameter becomes less. By these simple means the winding is effected very perfectly, the whole process being self-acting and entirely independent of the operative.

In making weft cops provision has to be made to counteract the taper of the spindle which is reversed in the cop, and this is easily done by using a small taper tube superposed on the spindle.

The Ashworth machine has the following important features:—

It is a continuous spinner.

It imparts a positive twist.

It builds either twist or weft cops on the bare spindle or paper tubes.

It will spin with ease counts hitherto beyond the capacity of any previously constructed continuous frame.

A ring spinning frame is also exhibited by the Société Alsacienne de Constructions Mecanique of Belfort and Mulhouse designed to spin on the bare spindle, and in order to overcome the difficulties of the case the speed of the spindle

is varied. The machine is electrically driven, and the current, on its way to the motor is passed through an arm attached to the building motion and receiving a corresponding reciprocal movement. The end of the arm passes over the terminals of a set of resistance coils, and directs the current through one or more of them, thus setting up a variable resistance and diminishing the current supplied to the motor. The result is that the speed of the latter is correspondingly diminished, and consequently that of the spindles. In work, therefore, after the bottom is formed, the spindles are increased in speed as the ring rail falls, and decreased as it rises in exact proportion to the diameter. The speed is regulated so that the ordinary speed of such spindles is exceeded when winding at the shoulder and falls below when winding on the nose. In this way a mean speed is obtained which prevents that loss of production which would otherwise take place. From 8,000 to 12,000 revolutions per minute represent the variation. The weak spot is the probable loss of current, or rather waste of current, in the resistances, and some figures on that point would enable a comparison to be made with the power ordinarily taken.

The Société Alsacienne have a very fine and extensive exhibit and among the machines shown is a self-acting mule, in which an attempt is made to drive by electro-motors instead of as usual a belt-pulley. It is well known to all who are conversant with the working of the mule that the power must always be in a position to be instantly applied. At the beginning of the cycle of movements the engagement of the rollers and the commencement of the running out of the carriage must be made without any pause. In other words, the full power must be applied at once, and from dynamometrical observations it is clear that it is so. Then again at the end of the twisting period the arrestation of the spindle and the reversal of its direction must also take place without break of continuity, and

similarly the inward draft of the carriage must follow at once on the termination of backing off. All this implies the necessary power being held in reserve for instant application, so that it has been customary to apply this power at one central point from which it can be distributed at will throughout the machine by means of suitable bands.

The Société Alsacienne attack the problem of driving the mule electrically by dispensing with the rim band. On the corresponding shaft to the rim shaft they mount an electric motor, which provides the necessary power for drawing in and drawing out the carriage. The actual rotation of the spindles during twisting and backing-off are the work of a second motor mounted in the square and running on a bush on the tin roller shaft, the loose half of the twisting clutch being fixed on the bush. There are two friction clutches mounted on the shaft, one of which acts during twisting and the other when backing-off. The motor and one half of each of the two clutches are always revolving, so that when the changes take place there is no delay. The loose half of the backing-off clutch is fastened with an internal annulus, with which gears a pinion on a counter shaft. On the other end of this shaft is a wheel gearing with a pinion fixed on the tin roller shaft. When the clutch is engaged the backing-off takes place perfectly. The dynamo in the head is also attached to a friction clutch on the shaft, by means of which the roller and drawing-out motions are controlled. The taking-in clutch is of the usual type, and is operated from the rim shaft in the ordinary way. The changes are made in a similar manner to the Platt mule, with, of course, such modifications of mechanism as are necessary to operate the friction clutches named.

The Société Alsacienne also exhibits a revolving flat-carding machine, the chief novelty of which is the method of working the flats, which are rotated in a direction opposite to that of the

cylinder, and are stripped at the feed and not the delivery end. This is entirely contrary to the usual practice, and it is difficult to appreciate the alleged advantages. These are that the waste is stripped at the point where most dirt is taken up, and that the cotton is better treated by clean flats as it approaches the doffer. It is urged that the sliver is cleaner than under the ordinary system, a statement which is partially true. On the other hand, it would appear from the appearance of the strips that a good deal of available cotton is taken out, and that there is much danger of the dirt escaping. The object of a card flat is to clean out dirt, nep, and short fibre. These, undoubtedly, are found at the feed end of the machine in greater quantity, and it is here that under the new plan they are presented to the flats. But the flats get gradually fuller of strips as they approach the feed roller, and are fullest just before leaving the cylinder, and it is precisely at this point that, in this instance, they have to receive and remove the greatest quantity of impurity. It appears to us that, except by also removing a good deal of fibre, the end is not likely to be served. The matter is one capable of proof by actual trial, but a record would be needed of the weight of waste removed, the strength of the yarn subsequently spun, and many other items. At the same time there is something in the contention that by permitting the seeds and leaf to go forward, they are broken up and rendered more difficult of removal. That they are not always removed is true, but in the main it is the other way.

In the machinery used for the preparation of wool there are several notable exhibits, and one or two new methods of practice shown. At the stand of the Société Anonyme Vervietoise pour la Construction de Machines there are two carding machines shown which are illustrated in Figs. 2 and 3. In the first, instead of arranging the cylinders as in a double carding machine one behind the other and connected by a tummer, the cylinders

are arranged one above the other, as shown. The purpose of this arrangement is to enable two different materials to be dealt with at once, or to double card the some material. As shown in Fig. 1 the machine can be fed by the two lattice aprons, A and B, and each cylinder then treats the material fed to it and

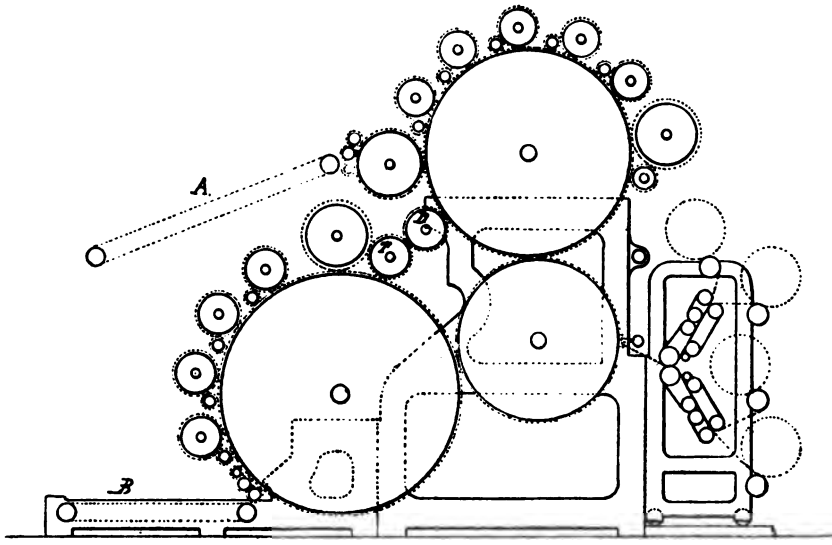


Fig. 2.

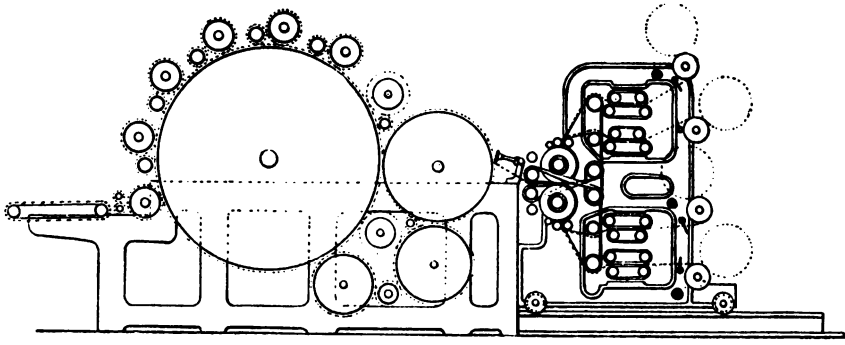


Fig. 3.

delivers it to the doffer, the web from the upper cylinder being superposed on that from the lower. If desired the material can be fed by the lower table A only, in which case it is first carded by the lower cylinder, and then by means of the rollers T and D transferred to the upper cylinder, where it is further carded and then delivered to the doffer. In the latter case the lower cylinder, after having transferred to T the insufficiently carded material, is itself stripped of any wool which is properly carded and delivers it to the doffer, where it unites with the web formed by the upper cylinder. The following advantages are claimed. The cylinders separately fed deal with less material each than is usually the case, but together give greater production. The doffed fleece is more even on account of the superposition of the two webs, and in consequence the condenser can be run quicker and produces better thread. If the wool be harsh it can be better worked by feeding the bottom cylinder only, and double carded. For coarse counts a heavy weight can be fed, the wool well carded, and a thick fleece produced. By feeding two colours a very good blend can be obtained. It is also claimed that from 10 to 25 % more production is obtained.

The machine shown in Fig. 3 is intended to remove from the cylinder, not only the long fibres but also, if desired, the shorter fibres. Two doffers are used and two fleeces obtained, which can be combined so as to utilise all the available material, and for the lower classes of yarn it is claimed that a very much larger production is got.

A rather remarkable exhibit is found in the Austrian section, where the firm of G. Josephy,s Erben, of Bielitz, show two carding engines, the construction of which is shown in Figs. 4 and 5, which being diagrammatic speak for themselves.

There are no British machines used in the finishing processes exhibited, while there are many foreign exhibits of that character. Among these the most notable is that of Mr. Fr.

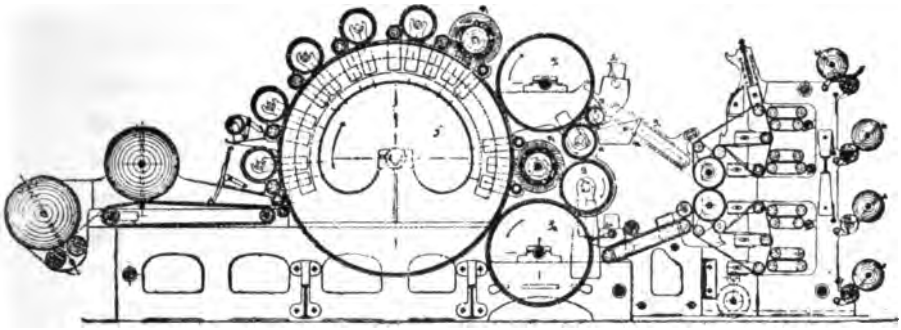


Fig. 4.

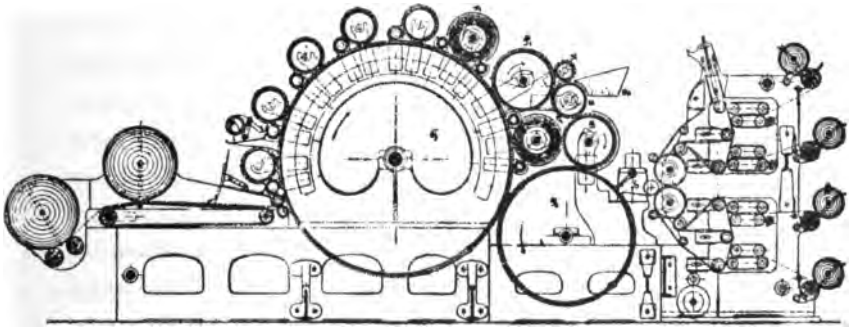


Fig. 5.

Gebauer, of Berlin, which is devoted to bleaching, finishing, and printing machines.

Among his exhibits is a hydraulic mangle having some points of interest. The bottom roll is carried by bearings in the framing, and the gearing is powerful and strong. The pressure of the upper roller upon the material is regulated by hydraulic rams and it revolves in bearings sliding in the side frames. The chief feature of the machine, however, is the method adopted to take out the mangle roll after mangling. Mounted on each end of the axis of the bottom roll within the frame are two discs provided with six radial slots. In these slots the mangle rolls are borne. The discs are of such a diameter that when any one

of the slots is in its upper vertical position, the centre of the roller bearings coincides with the centre of the roll when in working position. Three rolls are usually carried by the discs at one time. On one of them the cloth is being wound preparatory to treatment, from the second it is being unwound after mangling, while the third is in mangling position and the cloth is being treated. Thus, instead of having to stop the machine to take out the roll, the operation is a continuous one.

Dr. Kellner's patent electrolyser is of special interest, and has been designed to produce cheaply and readily a solution of hypochloride of sodium from a solution of common salt by electrolysis. The electrodes consist of glass plates covered with platina-iridium wire, which resists the destructive effects of nascent-chlorine. The electrodes are fixed in an earthenware cell which has two overflow pipes in its upper part and two openings at its lower end, into which hard lead pipes are fixed communicating with the centrifugal pump and enamelled receiver shown. A cooling coil of hard lead through which water constantly flows is fixed in the receiver. The solution of salt is prepared in a wooden vat, and the filtered solution is poured into the receiver which is completely filled. The centrifugal pump then draws the solution from the receiver and discharges it into the earthenware cell in which are the electrodes. The solution is decomposed and flows back by the overflow pipes to the receiver. The circulation is kept up until the solution is of sufficient strength, the chief factors being the concentration of the salt solution, the strength of the electric current, and the time of working.

It is claimed that when goods are chemicked in this way the fibre is not weakened, the penetration of the liquor is complete, and the process is cheaper and much more cleanly than the chloride of lime process.

An electrical speed-regulating device is shown, which has for its object the provision of means for regulating the speed at which electrically-driven calico-printing machines are run. The motors are of the continuous current type, and the regulation is, of course, effected by means of resistances introduced into the circuit. The speed can be regulated in the proportion of 1 to 3, with 15 steps, or as 3 to 10, with 13 steps, so that a considerable power exists to deal with a wide range of fabrics. The resistances are arranged so that there is a comparatively small loss of the effective power of the current, and the machine is provided with a hand wheel and pointer, traversing a figured dial, thus enabling the required speed to be obtained at will.

It may be fairly said of this exhibit that it exemplifies the great progress made by our continental competitors, as the design and quality of the machines are quite equal to the highest standard.

The difficulty which has been experienced in the packing of American cotton, and the extremely careless way in which it is packed, is resulting in the introduction of new modes of packing in the form of a round bale. The system adopted by Mr. Lowry varies from others, as instead of either pressing a mass of cotton by means of a ram, or of rolling it up under pressure, the material is fed in an entirely different method. The machine as illustrated herewith, Fig. 6, was exhibited by the Indo-Egyptian Compress Co. in the American section at Vincennes, and is constructed as follows :—

At the lower part is a hydraulic cylinder, which is connected with a relief valve weighted to a suitable pressure. Within the cylinder a hollow piston or ram works the head of the ram, carrying a round table on which (this is clearly shown in the illustration, the ram being shown up with a bale just begun) the pressed cotton bale is carried. By an arrangement afterwards

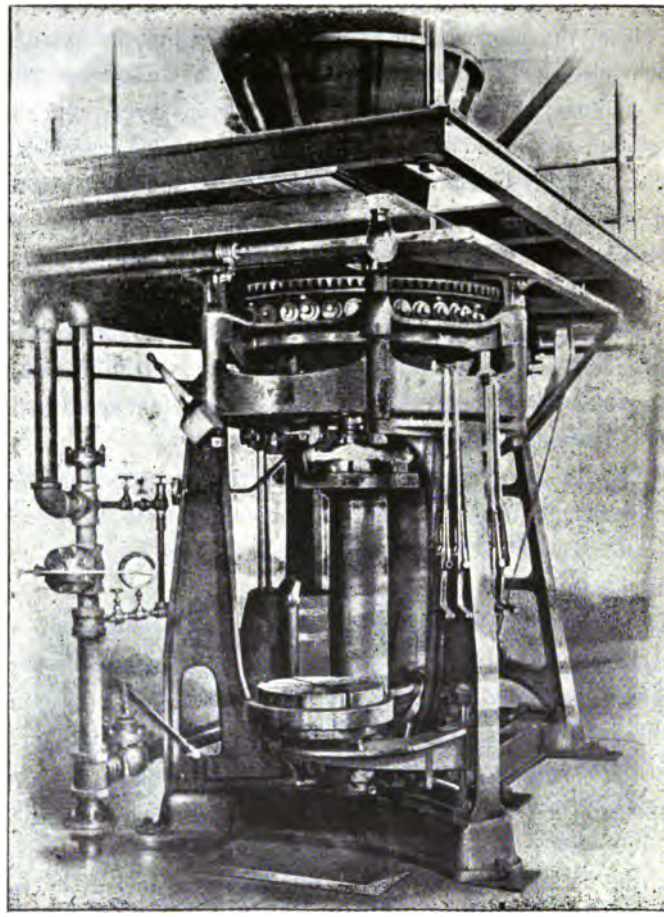


Fig. 6.

described the bale and table can be removed. The cotton is fed into the hopper shown, the head of the press which is below it being sustained by strong frames. In the head a cylinder is formed, the diameter of which is that of the bale, and upon the upper end of the cylinder a loose plate is superposed. This plate, which closes the foot of the hopper, is pierced by a

number of tangential slots extending from its periphery nearly to its centre, and a hole in its centre into which a long plug is pushed. The cylinder consists of two parts, one a short piece just below the plate, which is capable of revolution, and another one which is fixed and acts merely as a guide or delivery tube. The revolving cylinder is driven by the mechanism shown, and is sustained by a series of rollers between a wide flange fixed to it and a similar fixed flange or ring forming a roller bed, the friction being thus considerably reduced.

When bale is formed from lint cotton from a gin it falls into the hopper of the press. When a bale is being started the ram is raised to its highest point, closing the bottom of the cylinder, and a certain portion of the material is pushed through the holes in the plate until the cylinder is fairly filled up. The cylinder is then started, and in revolving carries with it the material enclosed within it. The frictional cohesion of the upper lays of material with that in the hopper draws the latter through the slots and adds it to the material within the cylinder, laying it in a number of coils round the central plug, thus forming a hollow core to the cylinders. As this constant accretion takes place the pressure on the cylindrical bale becomes greater, and the previously loosely packed material becomes more tightly pressed until a sufficient pressure is created to overcome the resistance of that in the hydraulic cylinder, and thus force the ram slightly downward. The exact point at which this yielding takes place is dependent upon the weighting of the relief valve, the ram substantially acting as an hydraulic buffer. The action of the press is therefore novel, because the pressure put upon the bale depends not upon the forcing upwards of a ram, but upon forcing it downwards. It is the accretion of the material on the bale in the manner described, combined with the defined resistance to the descent of the ram, which sets up the pressure, and by fixing the amount of the latter it can be made entirely

uniform throughout a series of bales. A density of 46lbs. per cubic foot is usually obtained. When the ram has reached a point sufficiently low the process is stopped, and a length divided from the pressed material. This is secured by wires, and removed from the machine, the ram run up, and the operation re-started.

Fig. 7.

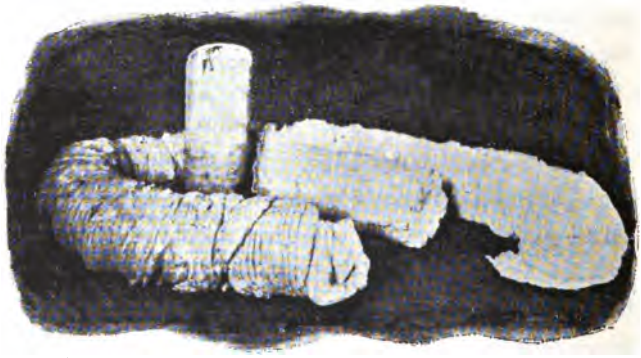


Fig. 8.

The appearance of the bale thus produced, as compared with the ordinary style of bale is shown in Fig. 7. The cover can be removed at any time to take a sample, and again replaced, there being no pressure on it, the whole stress being taken by the binding wires. It should be noted that in the Lowry bale the entire stress is lengthwise, the lateral stress being practically nil. When the bale is opened it is as shown in Fig. 8, and can be easily picked up and thrown on to a lattice or into a hopper without using a bale breaker at all. Hay and straw, hemp, and a variety of other articles can be packed in this machine.

So far as looms are concerned there are few exhibits in the British section, the most notable being an automatic terry loom shown by Messrs. Hacking & Co., of Bury, which fully bears out the reputation of the firm and this country. The looms exhibited by the Maschinenfabrik Ruti are very fine samples for silk manufacture, and in one or two instances there are some good cotton looms. The woollen looms exhibited are well made and contain motions which, although slightly modified, are British in origin. A loom made and designed by Messrs. Gulcher & Schwabe, of Biala, has been taken up in this country by Messrs. Hutchinson, Hollingworth & Co., of Dobcross.

In conclusion it may be said as matter for regret that there are no British exhibits in machinery for finishing textiles, or for knitting, lace making or embroidery. In each of these sections foreign exhibits are numerous, and there does not appear to be any reason why this country should not do some part of this work. The machines require skill in making but are well within the competence of our machinists. The general lesson is that while we need have no fear for our position, we ought to be vigilant and should abandon the idea that we alone are fit to be copied and have no need to look for examples elsewhere. While we are still ahead, thought is being exercised elsewhere, which means danger.

SECTION V.

Engineering Education - - Mr. F. C. FORTH.

The group of exhibits dealing with education and instruction was located near to the Eiffel tower in the buildings bounding the Champs de Mars. Every phase of education received more or less exemplification. Practically every country in Europe was represented, and in addition most of those in the western hemisphere. It will be gathered from these remarks that considerable space was allotted to the group in question. The writer spent more than two days inspecting the exhibits, paying special attention to the engineering section, and even then could make only a cursory examination of much that was on view.

Taking into account the limits imposed for this paper, it is not possible to do more than make some general comments on what was seen, and at the same time allude to several of the more conspicuous exhibits, restricting the remarks entirely to the engineering section.

THE FRENCH EXHIBIT.

As might have been expected the French exhibit far surpassed, both in extent and importance, that of any other country. The work from schools giving technical training was assembled so as to completely display the course of instruction pursued, each school having its own independent exhibit. Graded examples of smith-work, fitting, turning, pattern making, &c., were neatly arranged, and in such a manner as to admit of easy inspection. The note and exercise books of the students were also available, and, taken generally, the work contained in these was eminently neat and painstaking. A striking exhibit, and one that may be mentioned as a type of numerous others on view, was that of the Ecole Vaucanson of Grenoble. This

is a trade school, and showed various products of its industry, a small steam engine and a fly-press being especially noteworthy. Turning next to an institution of higher standing, the Ecole Nationale des Ponts et Chaussées exhibited a very complete collection of drawings and designs, the subjects consisting of iron and stone bridges, roofs, canal locks, &c.

The general impression left by this section was most pleasing, the careful arrangement of the exhibits, their extent and variety, the thorough systemisation, all showed a full recognition of the need for technical training and the determination of the schools to impart it.

Though in a separate building to the special education exhibit, it is worth referring at this point to the highly interesting display prepared by the City of Paris in connection with its water supply and its sanitary system. Drawings and models of reservoirs, pipes and valves, sewers, baths, w.c.'s, and other such fittings, together with samples of water and of sewage, and a life-like representation of a sewage farm formed a splendid object lesson. It is satisfactory to be able to observe that, judging from what was shown in this section, we in England are well ahead in respect to sanitary fittings and accessories.

The ingenuity shown here, and indeed throughout the exhibition, in graphically representing all kinds of statistical data was most remarkable.

THE ENGLISH EXHIBIT.

In the early part of this year an education exhibition was held at the Imperial Institute in London, the technical and other schools throughout England and Wales, contributing samples of their work. A considerable collection was then gathered together, and at the time it formed a most heterogeneous mass. The best of the examples shown at London, were selected, and these form the exhibit at Paris. The great

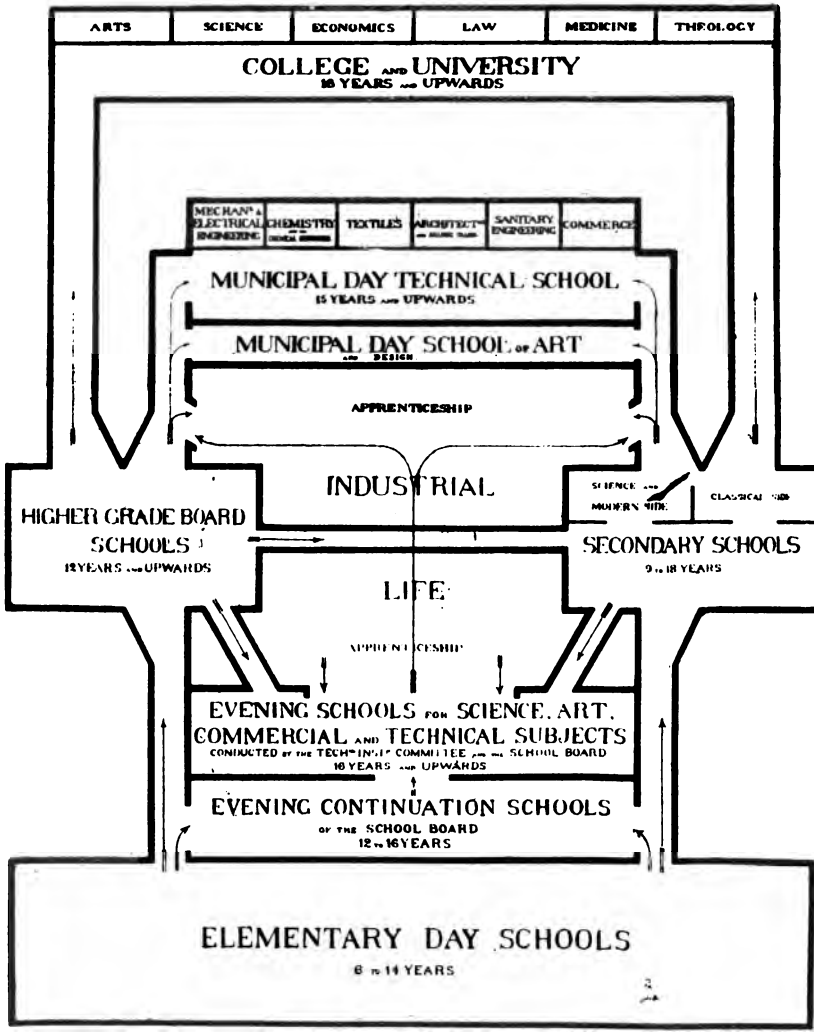


DIAGRAM ILLUSTRATING THE CORRELATION OF EDUCATION IN THE CITY OF MANCHESTER.

fault of the English exhibit, is its chaotic arrangement. No attempt appears to have been made to illustrate the systems pursued in the schools, samples of engineering work, of carpentry, of plumbing &c., being jumbled together in the most promiscuous fashion. Considering the examples individually however, there are many pieces of really good work, well finished and showing considerable skill and taste.

It is satisfactory to note that the educational system of Manchester has received commendation at the hands of the judges of this group, a diagram illustrating the co-ordination scheme of education now in force in this city having been awarded a gold medal. The diagram, a copy of which accompanies these remarks, was devised by Mr. J. H. Reynolds, the director of the Manchester Technical School. See page 180.

THE AMERICAN EXHIBIT.

An excellent impression was given by this exhibit. It was well planned, well displayed, and gave a thoroughly good idea of the educational methods in use in the United States. Typical schools had been selected and the whole course of instruction in each of these was fully shown.

The space at disposal being limited, photographs were largely employed. These were shown in ingeniously devised frames so arranged as to be compact and yet easily accessible. Specimens of work were stored in drawers and wall cases, whilst note books, pamphlets and statistical data were to be seen on tables close at hand.

The school selected as a type of a technical institution is the well known Massachusetts Institute of Technology. This institution has numerous departments, but confining the remarks to the engineering department only, the following information seems worthy of note.

The course of study in engineering extends over four years, the average age of the students at admission being eighteen years

eleven months. The entrance examination demands a sound knowledge of mathematics, a modern language, English and history, and mechanical drawing may also be taken as an optional subject. The candidate for admission must be at least seventeen years of age.

The course includes, besides the usual science subjects, instruction in hydraulics, machine design, laboratory practice, shop management, &c. The student may in his fourth year specialise in electrical, marine, or locomotive engineering, or in naval architecture. Military drill forms part of the course of instruction in this as in other American institutions.

Other institutions are referred to but the above-named sufficiently represents the type.

Speaking of the ages of students, the diagram representing the ages of students attending the Municipal Technical School, Manchester, may be of interest. It is certainly worthy of a careful examination. See page 184.

There is, curiously, no German educational exhibit, though it is to be noted that this country is very much in evidence everywhere else throughout the exhibition.

The engineering exhibits of other countries, though interesting enough in themselves call for no special remark.

The writer in visiting the exhibition went with a perfectly open mind, and with an earnest desire to discover the true relations existing between our educational system, as applied to engineering, and the systems in use in other countries. He feels strongly that the educational exhibit, as far as France is concerned, should not be considered apart from the exhibition itself. He also considers that the exhibition is a great triumph; firstly an artistic triumph, but most of all a triumph for the engineer. Turn where you will you see the engineer in evidence; in the majestic Eiffel Tower, in the huge globe, in the moving platform, in the steel skeletons of the magnificent

buildings, in the graceful Alexander III. bridge recently constructed across the Seine, in the electric light which makes the grounds so brilliant after dusk; and the thought presents itself how much of all this is due to the scientific and technical training of those engineers responsible for the work? How much of it could have been accomplished without such training? And if it be admitted that technical training is a factor in producing such results, would it not be to the point to ask what are we doing in this country to equip our youths and young men to carry on the struggle, and to maintain their position in that race for industrial supremacy in which, as the years pass on, the engineer is destined to take a greater and greater part.

It is for associations such as ours by their sympathy and advice to help on the education movement, especially in as far as it concerns engineers, and it is safe to say that those concerned in managing our educational institutions will at all times welcome such aid.

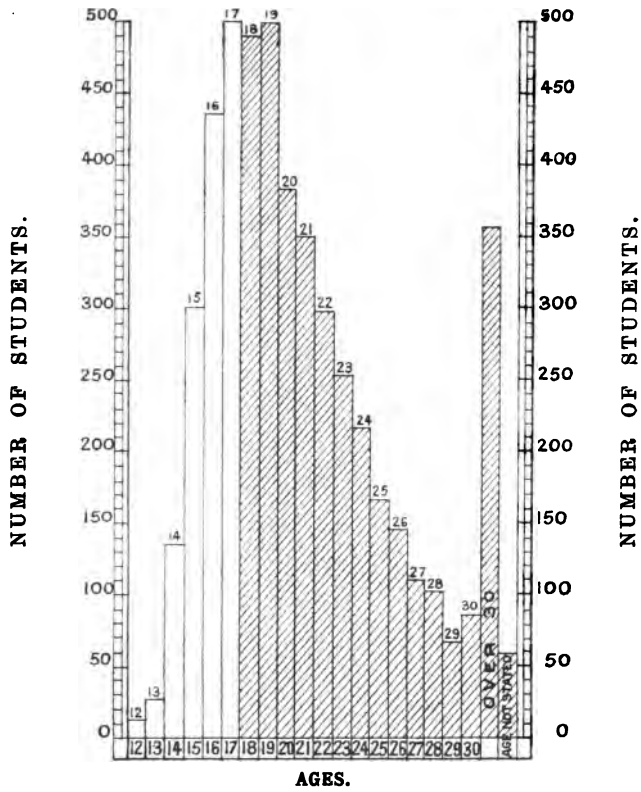
There is no occasion to fear for the industrial future of this nation, once we have become fully alive to the necessity of properly equipping our young men for their future career.

THE DISCUSSION WAS ADJOURNED TILL THE 3RD NOVEMBER.

APPENDIX C.

Municipal Technical School and Municipal School of Art.

DIAGRAM SHEWING THE NUMBER OF INDIVIDUAL STUDENTS OF GIVEN AGES FOR THE SESSION 1899-1900.



No. of Individual Students under 18 years of age.....1403
,, ,, ,, 18 years of age and over....3570

4973

In addition, there are 690 Pupil Teachers at the School of Art.

The proportion of Students 18 years of age and over (see shaded columns) to Students under 18 years of age (see unshaded columns) is as 5 is to 2.

FLYWHEELS.

READ SATURDAY, 27TH OCTOBER, 1900,

BY

Mr. ARCHIBALD SHARP, B.Sc., A.M.I.C.E.

LONDON.

INTRODUCTORY.

A flywheel in motion is a storehouse of energy, in which is accumulated any energy supplied by the prime mover in excess of that required to overcome the resistance. When the energy given by the prime mover at any instant is less than that required to overcome the resistance, the flywheel supplies the deficiency. A moving flywheel is therefore analogous to an hydraulic accumulator or a reservoir of water, in a less degree to a gas reservoir, a coal store, or a powder magazine; the latter aspect sometimes being presented in a most unpleasant manner. In the accumulator potential energy is stored, in the moving flywheel kinetic energy. When only small quantities of water have to be stored almost any receptacle may suffice; similarly when only a very small flywheel is wanted any heavy mass may fulfil the requirements satisfactorily. But as in designing a powerful accumulator or a large reservoir, the skill and experience of the engineer may be taxed to the utmost, so in designing a flywheel capable of storing great quantities of energy the problem may be a very difficult one.

In the present paper an attempt is made to briefly discuss the scientific principles underlying the design of flywheels, and to present in a convenient form some examples of the most advanced practice, while a few suggestions for further advances are offered.

KINETIC ENERGY.

The energy stored in a body weighing W lbs., moving with a linear speed v feet per second, is given by the well known formula :—

$$E = \frac{Wv^2}{2g}, \quad - \quad - \quad - \quad (1)$$

E being measured in foot lbs. The formula is discussed in all elementary treatises on mechanics, and can be easily verified by a direct experiment on a small flywheel. The formula expresses the fact that the energy stored is proportional to the weight of the moving body, and to the square of its linear speed. In other words, while by doubling the weight of a flywheel running under given conditions its effectiveness or powerfulness is doubled, by doubling its speed its powerfulness is increased four-fold. If the thickness of a flywheel rim is small compared with its diameter the average linear speed may be taken as that of a point at the middle of the rim thickness. The formula is exact for a flywheel of any shape whatever, if v be taken as the speed of a point at a distance from the centre of the wheel equal to the radius of gyration. In a short paper like the present there is no time to discuss moments of inertia, radii of gyration, and the like; sufficient to say that it is usually accurate enough for the designers' purpose to estimate the energy stored in a flywheel by taking v at the middle of the rim thickness, and W equal to the weight of the rim plus one-third the weight of the arms, plus $\frac{1}{20}$th to $\frac{1}{50}$th the weight of the boss.

In a flywheel the energy stored is due to its speed: when at any instant the power of the motor is greater than that required to overcome the resistance the speed of the flywheel is being increased. The storage capacity of any flywheel, therefore, depends on the greatest speed at which it can be run with safety.

In flywheels of small steam engines and gas engines the speed of the crank shaft is usually determined from considerations

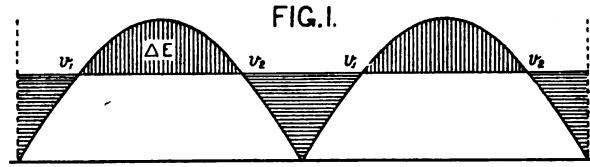
other than the flywheel. Considerations of space naturally limit the size of the flywheel, and it follows that these flywheels are usually run at comparatively low speeds. The advantages due to high rim speed are more than counterbalanced by disadvantages of large diameters in comparison to the size of the engine, or by the necessity of gearing the flywheel shaft to a higher speed of rotation than the crank shaft. The desired storage of kinetic energy is therefore obtained by taking the flywheel rim of sufficient dead weight. In larger engines where greater stores of energy are required, higher rim speeds are practicable, and in fact rim speeds are used as nearly as can be ventured up to the safe limit.

ENGINE UNDER STEADY LOAD.

Variation of Crank Effort.—The turning effort on the crank of a steam engine varies periodically, being zero at the dead centre, and attaining its greatest value when the crank is somewhere about right angles to the line of stroke. The exact position of the crank for maximum turning effort depends on the shape of the indicator diagram, and the inertia of the reciprocating parts. If the indicator diagram be given, the weight of the reciprocating parts, the stroke and the number of revolutions per minute be known, a curve can be drawn showing the variation of the turning effort on the crank during one revolution. The most convenient curve for the flywheel designer is one in which the circumference of the crank pin circle is set off as a straight line, the different positions of the crank pin being indicated as abscissae, and the corresponding tangential effort on the crank as ordinates. Fig. 1 shows such a curve for a non-expansive double-acting steam engine, the horizontal distance between the two vertical dotted lines corresponding to one revolution of the crank shaft. The obliquity of the connecting rod and the inertia of the moving

parts are neglected in Fig. 1. The ordinate to the horizontal straight line represents the steady resistance against which the engine is working.

FIG. 1.



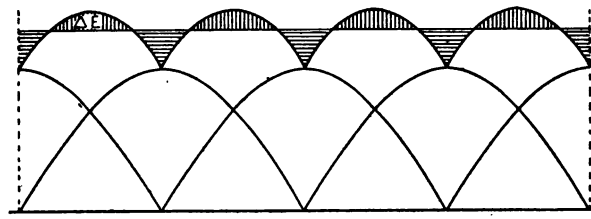


FIG. 2.

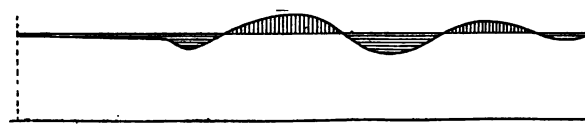


FIG. 3.

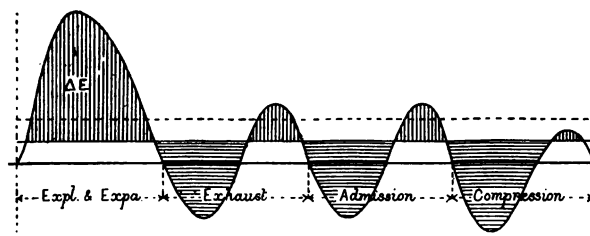


FIG. 4.

It will be noticed that at the dead points the turning effort on the crank is zero, and therefore the flywheel has to supply the deficiency of energy. As the crank turns away from the dead centre the turning effort gradually increases till a point is reached where it is just equal to the resistance, this point is indicated by v_1 on the diagram. Up to this point the speed of the

flywheel has been decreasing, beyond this point the turning effort is greater than the resistance, and the excess energy is expended in increasing the speed of the flywheel, Towards the end of the stroke a point v_2 is reached at which the turning effort has diminished and become equal to the resistance; still nearer the end of the stroke the crank effort is less than the resistance, and energy has to be supplied from the flywheel. The area included between the base line and the mean resistance line in Fig. 1 evidently represents the work done by the engine in one revolution, this must evidently be equal to the area included between the base line and the curve. The shaded area $\triangle$ E represents the kinetic energy stored in the flywheel in increasing its speed from the minimum value v_1 to the maximum value v_2. The shaded areas above the straight line must evidently be equal to those below, while the engine is running steadily. In one revolution therefore the speed of the flywheel has two maximum and two minimum values. Fig 2 is a similar diagram for an engine with twin cylinders, cranks at right angles, pressure constant throughout, inertia of moving parts neglected. The top curve is obtained by adding together the ordinates to the two curves from the two cylinders, and it will be at once noticed that the excess energy $\triangle$ E in this case is very much less than in Fig 1. Fig. 3 is a similar curve for a triple expansion engine actually obtained from indicator cards, and corrected for inertia of reciprocating parts. Fig. 4 is a similar crank effort diagram for a gas engine on the Otto cycle, corrected for inertia of reciprocating parts, There is no work done during the exhaust and admission strokes, while a negative quantity is done during the compression stroke. At the beginning of each stroke the driving pressure of the crank pin due to the pressure on the piston is diminished by the force necessary to accelerate the reciprocating parts. Hence the *negative* driving effort at the beginning of the exhaust, admission and compression strokes.

The dotted horizontal line is the mean resistance line when two gas engines are coupled on to the same crank axle, the cranks being in line. The value of $\triangle$ E for a two-cylinder gas engine is not nearly reduced in the same proportion as in the case of a two-cylinder double acting steam engine, as a comparison of Figs. 1, 2 and 4 will show. In other words the increased steadiness of running obtained by coupling two gas engines to the same crank shaft, is not nearly so great as that obtained by coupling two steam engines with cranks at right angles. Comparing Figs. 1 and 4, the resistances are nearly in the ratio 4:1, while the excess energies $\triangle$ E are about 1:2. For equal steadiness of running therefore, a gas engine should have a flywheel of about seven or eight times the weight (or more correctly the moment of inertia) of that of a single-cylinder steam engine of equal power and speed of revolution.

Fluctuation of Energy.—The ratio of the energy stored in the flywheel, while passing from its minimum to its maximum speed, to the total work done by the engine in one revolution, is called the *fluctuation of energy*. This ratio does not depend to any great extent on the size or speed of the engine, but principally on the number of cylinders and arrangement of cranks. Table I., giving the values for a few cases, is taken mainly from Cotterill; the values for the gas engine have been roughly estimated by the author.

Table I.—Fluctuation of Energy.

Length of Connecting Rod	Double-acting Steam Engine. Pressure constant throughout stroke.			Gas Engine. Otto Cycle.		
	One Crank	Two Cranks at 90°	Three Cranks at 120°	One Crank	Two Cranks in line	Two Cranks opposite
Infinite ..	·11	·011	·003	·75 to ·85	·25 to ·30	·50 to ·60
Six Cranks..	·12	·031	·008			
Four Cranks	·14	·042	·011			

Fluctuation of Speed of Flywheel.—The excess energy $\triangle$ E of the crank effort diagram is expended in increasing the speed of the flywheel from v_1 to v_2 Therefore

$$\triangle E = \frac{W}{2g}(v_2^2 - v_1^2)$$
$$= \frac{W}{2g}(v_2 + v_1)(v_2 - v_1) = \frac{W}{2g} 2v \triangle v$$
$$= \frac{W v^2}{2g} \cdot 2 \frac{\triangle v}{v},$$

v being the average speed, and $\triangle v$ the difference between the maximum and minimum speeds v_2 and v_1. But the average total energy E stored in the flywheel is equal to $\frac{W v}{2g}$, therefore the above equations becomes

$$\frac{\triangle E}{E} = 2 \frac{\triangle v}{v} \qquad (2)$$

$\frac{\triangle v}{v}$, the ratio of the *difference* between maximum and minimum speeds to the *average* speed of the flywheel is called the *fluctuation of speed.* $\frac{\triangle E}{E}$, the ratio of the difference between maximum and minimum energy to the *average* energy stored in the flywheel, may be called the *fluctuation of kinetic energy.* Equation (2) may be expressed thus:—The fluctuation of kinetic energy of the flywheel is equal to twice the fluctuation of speed.

In engines driving textile machinery, according to Unwin, the fluctuation of speed allowed is from $\frac{1}{50}$ to $\frac{1}{100}$. In engines driving electric lighting plant the fluctuation of speed allowed is $\frac{1}{100}$.

Equations 1 and 2, and the value of $\triangle$E as derived from a crank effort curve, are all the data required to calculate the W and v of a flywheel to suit given conditions of fluctuations of energy and speed. Table II has been prepared to facilitate flywheel calculations; column 1 contains various speeds, column

2 the number of foot-tons of energy stored per ton weight of rim, and reciprocally, column 4 contains the number of tons weight of rim required to store 1,000 foot-tons kinetic energy.

Example.—Two-cylinder engine, cranks at right angles, 100 revolutions per minute, 1,000 IHP, fluctuation of energy from crank effort diagram 0·05, fluctuation of speed not to exceed $\frac{1}{100}$. The work done per revolution is

$$\frac{1{,}000 \times 33{,}000}{100} = 330{,}000 \text{ foot-lbs.} = 147{\cdot}5 \text{ foot-tons.}$$

$\triangle$ E = ·05 × 147·5 = 7·35 foot-tons. Substituting in equation (2), $\frac{7{\cdot}37}{E} = \frac{2}{100}$. Therefore E = 368·5 foot tons.

If the mean rim speed be 75 per second, from Table II., column 4, we find that to store 1,000 foot tons requires 11·40 tons weight of rim. Therefore required weight of rim is 11·4 × ·3685 = 4·2 tons.

Table II.

1	2	3	4	5	6	7
Mean speed of Rim.	Total energy stored per ton weight of rim.		Weight of rim required to store		Hoop tension in plain ring due to its own weight	Centrifugal tension in prismatic arm due to its own weight.
			1,000 foot tons	100 H.P. mins.		
Ft. per sec.	Foot tons	H.P. mins.	Tons.	Tons.	Tons per sq. in.	Tons per sq. in.
25	10	·7	102·40	151·76	·03	·02
50	39	2·6	25·60	37·94	·12	·06
75	88	5·9	11·40	16·88	·25	·12
100	156	10·5	6·40	9·49	·47	·23
125	247	16·5	4·08	6·08	·73	·36
150	351	23·7	2·85	4·22	1·05	·52
175	475	32·2	2·08	3·08	1·43	·71
200	625	42·1	1·60	2·37	1·87	·93
250	970	65·9	1·02	1·52	2·92	1·46
300	1406	94·9	·71	1·05	4·20	2·10
350	1910	128·9	·52	·77	5·73	2·84
400	2500	168·6	·40	·59	7·48	3·74

ENGINES RUNNING UNDER VARIABLE LOAD.

In most engines the load does not long remain steady, while in some engines, *e.g.*, for rolling mills, and for central power

houses of electric lighting and traction installations, the load on the engine varies tremendously from moment to moment, and the flywheel has to be designed to meet the severe requirements. Fig. 5 is a typical curve showing the variation of the load at the central station of an electric tramway, from which it will be seen that the power required may vary within a small fraction of a minute about 50% above and below the mean value. In such cases the flywheel has to be designed to store practically about half the power developed by the engine during several revolutions.

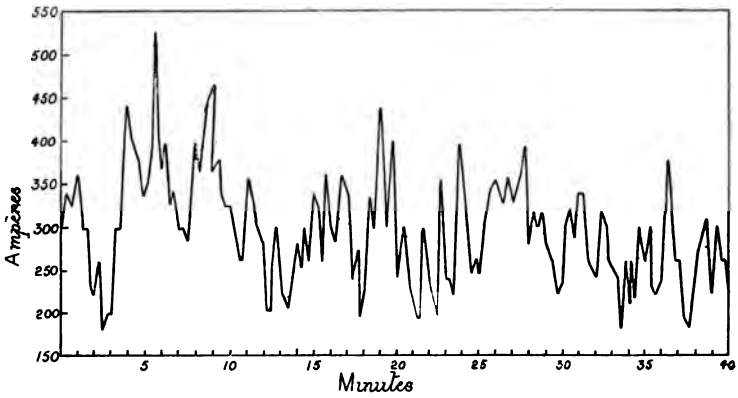


FIG. 5.

Columns 3 and 5, Table II., giving respectively HP minutes stored per ton weight of rim, and weight of rim required to store 100 HP minutes, are useful for such cases.

Example.—Find weight of flywheel capable of absorbing all the work done by a 1,000 HP engine during ten seconds, with only 10% increase of speed. Here $\Delta E = \frac{1,000 \times 10}{60} =$ 166·7 HP minutes, $\frac{\Delta v}{v} = \frac{10}{100}$. Substituting in equation (2) we get $\frac{166 \cdot 7}{E} = \frac{2 \times 10}{100}$, from which E = 833 HP minutes. If the average rim speed is 75 feet per second, by consulting column 5,

Table II, we find the required weight must be $8{\cdot}33 \times 16{\cdot}88 =$ 141 tons. If the average rim speed could be as high as 200 feet per second the required weight would only be $8{\cdot}33 \times 2{\cdot}37 =$ 19·7 tons.

This example compared with the previous one may give a clear idea of the demands made on the flywheels of an electric tramway plant. It may be remarked, in passing, that a gas engine is practically as good as a steam engine under a variable load, in the matter of flywheel capacity required for good governing.

Flywheels and Governors.—The influence of the flywheel on the regulation of an engine under a fluctuating load is not so generally understood as it deserves to be. Many makers of governors speak of them as being able to regulate an engine within a certain fluctuation of speed, when the whole load is suddenly thrown on or off. Most treatises on the subject discuss mathematically the governor considered as a tachometer, friction and inertia resistances; while the flywheel gets no mention or is dismissed with the remark that it is good to have a powerful flywheel as it gives the governor time to act. Such treatises, not realising some of the most important conditions of the problem, are of little practical use. The fact is the governor and flywheel act in conjunction. At one extreme, if the rotating parts are very light, even with an ideal governor, the speed would vary tremendously as the load fluctuated. At the other extreme, with an extremely powerful flywheel and a most rudimentary governor the speed would not vary very quickly.

In discussing the regulation of the speed of an engine there are three independent elements to be considered, the governor, the flywheel, and the work which can be done by the steam already admitted to the cylinder on its further passage to the engine, and over which the governor has no control. In Fig. 6, first published by the author in Proceedings Inst. Civ. Eng.,

vol. cxx., p. 268, an attempt is made to show the combined influence of the three independent elements. If the position of

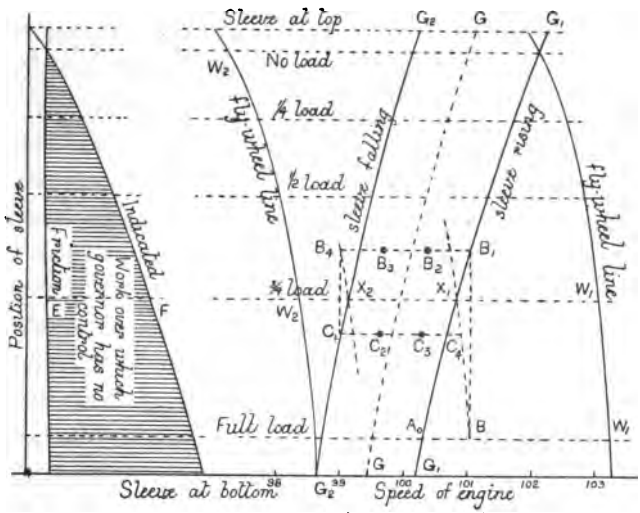


FIG. 6.

the governor sleeve be represented by vertical ordinates, and the corresponding speed of the engine as abscissae, the dotted curve G G will give the characteristic of the governor, regarded simply as a frictionless tachometer. The influence of friction of the parts to be moved by the governor can be represented by the curves G_1 and G_2, the curve G_1 giving the relation between the position of the governor sleeve and the speed of the engine when the sleeve is rising, and the curve G_2 when the sleeve is falling. This method of representing the characteristic of a governor is due to Professor Dwelshaver-Dery, of Liege. The left-hand portion of the diagram represents the work done by the steam over which the governor has no control. In a single-cylinder expansive engine this would be at least equal to the work done during expansion, in a triple expansion engine it might be equal to the work done per stroke in the

high pressure cylinder, plus twice the work done in the intermediate cylinder and three times the work per stroke in the low pressure cylinder. If, when the position of the sleeve and speed of the engine are represented by the point X_1, the whole load is thrown off the engine, the work E F may be expended in increasing the speed to the value represented by W_1. The more powerful the flywheel the smaller will be the increase of the speed X_1 W_1. Similarly, if when the sleeve position and the engine speed are represented by the point X_2, the maximum load be thrown on the engine, the speed may fall to the value represented by W_2. If the necessary data for drawing the curves G_1 G_1, G_2 G_2, W_1 W_1, and W_2 W_2, are available the greatest possible speed variation due to fluctuation of load would be clearly shown on the diagram. Suppose, for example, the engine is running steadily at full load and one-fourth of the load is suddenly thrown off, the increase of speed may be the difference between A_0 W_1 and X_1 W_1. If there be drawn through X_1 a line similar to the flywheel line W_1 W_1 cutting the line of full load at B, and from B be drawn a vertical line B B_1, cutting the governor line G_1 G_1 at B_1, the speed of the engine increases by the amount A_0 B, and the sleeve of the governor rises to B_1.

But this position of the sleeve corresponds to a smaller load (if the curves be as shown in the sketch) than that actually on the engine, and therefore the speed falls; the speeds at the end of successive strokes being represented by the points B_2 and B_3. If the speed falls to B_4, lying outside the flywheel line G_2 G_2, the governor sleeve falls to the position C_1. This position corresponds to a greater load than that actually on the engine, and the speed consequently increases at the end of successive strokes, being represented by C_2 C_3 C_4, and the same cycle of operations is repeated.

The accurate determination of the governor lines G_1 G_1 and G_2 G_2 is a matter for experiment, as they take account of

frictional resistances of joints, bearings, and stuffing boxes. The accurate estimation of the work over which the governor has no control is also difficult. The determination of the flywheel lines W_1 W_1 and W_2 W_2 presents no difficulty. The more powerful the flywheel the more closely will the flywheel lines W_1 W_1 and W_2 W_2 lie to the corresponding governor lines G_1 G_1 and G_2 G_2.

From this diagram some important conclusions may be drawn. If the flywheel line and the governor line slope in opposite directions, on a change of load the governor sleeve will oscillate for some time before taking up a steady position. If the flywheel is not very powerful, so that the flywheel line is less steep than the governor line, the governor will hunt persistently, and the sleeve will travel suddenly from top to bottom positions. This defect, generally attributed to over-sensitiveness of the governor is really due to insufficient flywheel power. If the flywheel is so proportioned as to make the flywheel lines vertical, the engine settles down most quickly to its new speed after a change of load. If the flywheel is still more powerful so that the flywheel lines slope in the same direction as the governor lines, after a change of load the engine quickly approaches its new speed of steady running and does not over-shoot it.

STRESSES ON FLYWHEEL.

We have already seen that if the speed of a flywheel can be doubled its weight can be reduced to one-fourth and yet give the same effect, we must now consider the limitations of speed beyond which we cannot go. Newton's first law of motion expresses the fact that every body continues in a state of rest or of uniform motion in *a straight line* unless acted on by external force. Now each particle in the rim of a flywheel does not move in a straight line, consequently while the flywheel is moving each particle must be acted on by the force necessary to

give it its circular path. This force is called *centripetal* force, and the equal and opposite reaction is called *centrifugal* force. At high speeds the centrifugal forces developed in a flywheel may lead to its destruction; let us now consider some of the principal stresses due to the centrifrugal forces.

Centrifugal Stress in plain ring rotating about its centre—Let a plain ring 1 inch wide, t inches thick, and r feet radius rotate about its centre with linear speed v feet per second. Let w lbs. be the weight of one cubic inch of the material from which the ring is made. Then from the well known formula for centrifugal force, $F = \frac{Wv^2}{gr}$ the centrifugal force on each inch length of the ring's perimeter is $\frac{wtv^2}{gr}$. Consider the equilibrium of one-half ring A C B (Fig. 7). The centrifugal forces, all directed radially outwards, produce a state of stress in the ring exactly like that in a boiler shell subjected to internal pressure. These centrifugal forces on the half ring have a resultant $\frac{wt.v^2}{gr} \times 2 \times 12r = 2\frac{wtv^2}{gr}$, $12r$ being the radius of the ring in

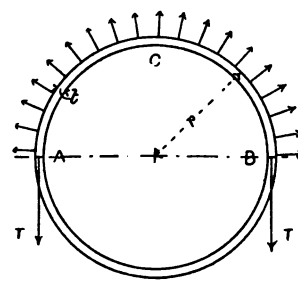


FIG. 7.

inches. This is balanced by the two tensile forces T exerted by the other half ring at the sections A and B. If f be the cutensity of the hoop tension $T = ft.$, and therefore $2\frac{12wtv^2}{g} = 2\,ft.$, that is $f = \frac{12wv^2}{g}$

If $s = 12w$ = weight of one foot length of rim one square inch sectional area, the formula for the hoop tension becomes

$$f = \frac{sv^2}{g} \quad - \quad - \quad (3)$$

Thus the hoop tension in a ring rotating about its own centre depends only on the linear speed and the density of its material; it does not depend on the thickness of metal or directly on the radius of the rim or the speed of rotation, except in so far as these influence the linear speed.

In Table II, column 6, the hoop tensions for various speeds are given, cast iron being taken as the material; the values for steel are about 8% greater owing to its slighter greater density. From the Table it will be seen that cast iron having a tensile strength of about 11 to 12 tons per square inch should burst at a lineal speed of 500 feet per second. This hoop stress exists in all flywheel rims, but, as we shall presently see, it is in many cases much smaller than other stresses. It is often stated that a flywheel with cast iron arms and rim has a factor of safety of 15 to 18 when running at a rim speed of 100 feet per second; this means that the calculator has only taken into account the hoop stress due to a plain ring rotating at that speed. The condition of a flywheel rim constrained at various points by the arms is totally different, and the numbers 15 to 18 can only be regarded as factors of ignorance, not of safety.

Centrifugal Tension on Arms due to their Own Weight.—If a flywheel is of uniform section throughout, and v is the rim speed, it can easily be shewn that the maximum centrifugal tension due to its own weight is $\frac{sv^2}{2g}$; a value half that of the hoop tension on the run.

Since the kinetic energy stored in the arm is

$$\frac{Wv^2}{6g}, \quad - \quad - \quad (4)$$

one third that of an equal weight of rim, it follows that the total energy that can be stored in a prismatic bar (Fig 19) rotating about an axis through its middle is two-thirds that of an equal mass in the shape of a plain ring made from the same material.

Column 7, Table II., contains values of the centrifugal tensions on the arms for various speeds.

Bending Stresses on the Rim Due to Centrifugal Forces.—In In Fig. 8, the dotted circle represents a part of the circular rim of a flywheel at rest, two adjacent arms being shown. When the flywheel is running the centrifugal forces tend to bend the rim into the form shewn, greatly exaggerated, by the continuous line, the arms restraining in places the outward motion of the rim. Thus, the rim is somewhat in the same condition as that of a long continuous beam uniformly loaded and supported at intervals. If the rim is made in segments the strength to resist bending may be impaired at the joints. Fig. 9 represents the condition of the rim segment when the joints are at the

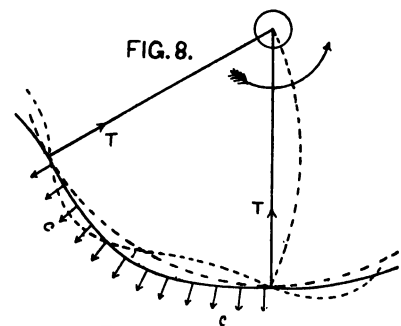


FIG. 8.

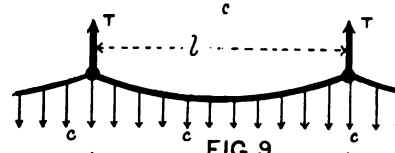


FIG. 9.

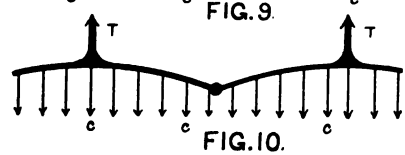


FIG. 10.

extremities of the arm, Fig. 10 when the joints are midway between the arms; it being assumed that the joints offer no resistance to bending. In Fig. 9, if c be the centrifugal force per inch length of the rim corresponding to the pull T of the arms, the maximum bending moment, which occurs midway between the arms, is approximately $\frac{cl^2}{8}$. In Fig. 10, the maximum bending moment, is also $\frac{cl^2}{8}$ but occurs at the section at the end of the arm.

If, therefore, the arms take up all the centrifugal force of the rim, and the rim be of symmetrical cross-section, joints at the ends of the arms are no better than joints midway between the arms. The condition as to hoop tension being zero is seldom satisfied however, and as we shall see from other considerations as well as experiments, joints midway between the arms are generally least satisfactory.

In a flywheel made in one casting the maximum bending moment will be given by a similar formula, *i.e.* it will be proportional to cl^2 but the divisor will be greater than 8. The maximum tensile or compressive stress f on the section due to bending is given by the well known formula $M = Zf$. In a flywheel rim of rectangular section, $Z = \frac{bt^2}{6}$, c is proportional to bt; substituting in the formula $M = Zf$, we find that btl^2 is proportional to bt^2f, *i.e.* f is proportional to $\frac{l^2}{t}$ - (5)

That is, the maximum stress due to centrifugal bending of the rim is proportional to the square of the unsupported length, or for wheels of the same diameter and speed, inversely proportional to the square of the number of arms. The formula also shows that the maximum stress is inversely proportional to the rim thickness, thus disposing of the popular fallacy that a belt pulley rim is not strengthened by increasing its thickness.

This fallacy has obtained currency by considering only the hoop tension (equation 3) and neglecting the bending stress, which is in most cases of vastly greater magnitude.

Bending of Arms and Rims due to Acceleration. The dotted lines in Fig. 8 show, greatly exaggerated, the nature of bending on the arms and rims due to fluctuation of speed, or steady driving from the boss to the rim. The arms have to be made strong enough to resist very sudden stoppages; the requirements for flywheels for electric traction being specially severe. Many flywheel accidents occur from sudden stoppages, but the damage done is not usually so great as in accidents due to excessive speed. Many flywheels are specified to be safely stopped in less than one revolution from full speed. When a wheel is wrecked from sudden stoppage the arms break off sometimes at one end, sometimes at the other; the rim pieces may drop quietly into the wheel pit, or be found not far away.

Hoop Tension and Bending Stress combined. In Figs. 9 and 10 it has been tacitly assumed that there is no hoop tension on the rim. In a cast iron flywheel with rim and arms in one piece it might be possible to deduce by the mathematical theory of elasticity the tension on the end of each arm, but with a flywheel built up of segments it would be difficult. In most cases the tensile stress due to bending is much greater than the hoop tension. In a flywheel with rim of rectangular section (Fig. 11) running at a rim speed of 200 feet per second and just on the point of bursting, the hoop tension might be $1\frac{1}{2}$ tons per square inch, while the maximum tension and compression due

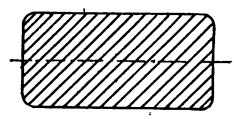


FIG. 11.

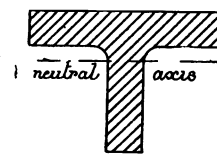


FIG. 12.

to bending might be something like $7\frac{1}{2}$ tons per square inch. Consequently on the section subjected to the greatest bending moment there would be a maximum tensile stress of 9 tons per square inch, and a maximum compressive stress of 6 tons per square inch. Such conditions of stress are unsuited for cast iron, they are, in fact, what would occur in a Hodgkinson cast iron beam turned upside down. Rim segments of T section (Fig. 12) jointed at the extremities of the arms so as to offer little or no resistance to bending at the joints, would give a much better construction. A glance at Fig. 9 shows that the outer flat part of the rim would be in tension due to the bending, the web of the T in compression; say 4 and 8 tons per square inch respectively. Adding the hoop tension we get the maximum tension $5\frac{1}{2}$ tons per square inch, the maximum compression $6\frac{1}{2}$ tons per square inch, and at equal speeds the wheel is much safer than that with rectangular section. If, however, the condition of things shown in Fig. 10 is approached, the T section rim will be much worse than the rectangular, the maximum tension being, under the same conditions, $9\frac{1}{2}$ tons per square inch, maximum compression $2\frac{1}{2}$ tons per square inch.

Bending of Rim due to Joints. It often happens that the mean line of resistance of the bolts, dowels, or cotters, fastening the rim segments together does not lie in line with the centre of the rim. In such a case the bending stresses induced may be very much greater than those due to hoop tension. The ordinary flange joint midway between the arm is a very bad offender in this respect, and should not be tolerated in a flywheel or pulley intended to run normally at a speed over 75 feet per second. When the axis of the stress on a strut or tie of rectangular section deviates from the centre of the section an amount equal to $\frac{1}{6}$th of the thickness, the maximum stress is doubled. In an ordinary flange joint the deviation may be from

1 to 1½ times the thickness, and the additional stress is 6 to 9 times the hoop tension.

Prof. Benjamin's Destructive Tests at High Speed.—Prof. Benjamin, of the Case School of Applied Mechanics, Cleveland, Ohio, possesses an apparatus with which he can test to destruction small flywheels up to 24in. diameter. Some of his experimental results have been published in the Proceedings of the American Society of Mechanical Engineers. Solid wheels 15in. diameter burst at rim speeds varying from 192 to 430 feet per second. Wheels with joints in the rims burst at speeds varying from 184 to 196 feet per second. The tangent spoke flywheel, illustrated in Fig. 16, burst at a rim speed of 425 feet per second. In his conclusions he says:—

"Flywheels with solid rims of the proportions usual among engine builders, and having the usual number of arms, have a sufficient factor of safety at a rim speed of 100 feet per second, if the iron is of good quality and there are no serious cooling strains. Rim joints midway between the arms are a serious defect, and reduce the factor of safety very materially. Joints made in the ordinary manner with internal flanges and bolts are probably the worst that could be devised for this purpose; under the most favourable circumstances they have only about one-fourth the strength of the solid rim, and are particularly weak against bending."

MATERIALS.

Cast Iron with its low tensile strength is not an ideal material for use in flywheels running at the highest possible speed. On the other hand, for wheels of small engines which are never required to attain a rim speed approaching 100 feet per second, the convenience of casting gives it the preference to all other materials.

Steel plate has been used for the rims and webs of very large flywheels for electro traction purposes; but the cost of such

wheels must be prohibitive to their extensive adoption. (See Figs. 14 and 15). Mild steel rods and bars have been used by the author for the spokes of flywheels. (Fig. 16).

Cast Steel has been successfully used for large flywheels (see Fig. 15). It could be economically used for the rims of wheels of the type shown in Fig. 16.

Wood flywheels are seldom seen in this country, and at first sight wood may seem a most unpromising material for flywheel construction. In itself however wood is a much better material than cast iron. Considering hoop tension alone the limiting speed for cast iron is about 500 feet per second. Taking the tensile strength of wood as one-fifth that of cast iron, and its density one-tenth, its limiting speed would be over 700 feet per second. But in resisting bending stresses the advantage is still greater. Taking two flywheel rims of wood and iron respectively, of the same diameter, width and weight, the thickness of the wood rim is about ten times that of the iron rim. The bending resistance of a section depends on the *square* of its depth, and the bending resistance of the wood rim will be about twenty times that of the iron rim. I have here two short beams of wood and iron respectively, of the same length, width and weight; the wood beam is therefore much thicker than the iron one. While the iron beam is too thin to support its own weight the wooden beam is fairly rigid. In flywheels which are also used as driving wheels, either for belts or rope, the use of wood as a material ought to be more seriously considered. I believe that if suitable preparations for their manufacture were made, the wooden rope-driving flywheel or pulley would make even more rapid headway than the wooden belt-driving pulley has done. The great drawback to the use of wood in flywheels, as in other structures, is the difficulty of making joints to resist tension, with a fairly high efficiency.

EXAMPLES OF RECENT PRACTICE.

Hinkley's Band Saw Pulley.—Fig. 13 shows a cast iron wheel which has been successfully used at high speeds for band-saw mills; it was invented by G. M. Hinkley and has been used

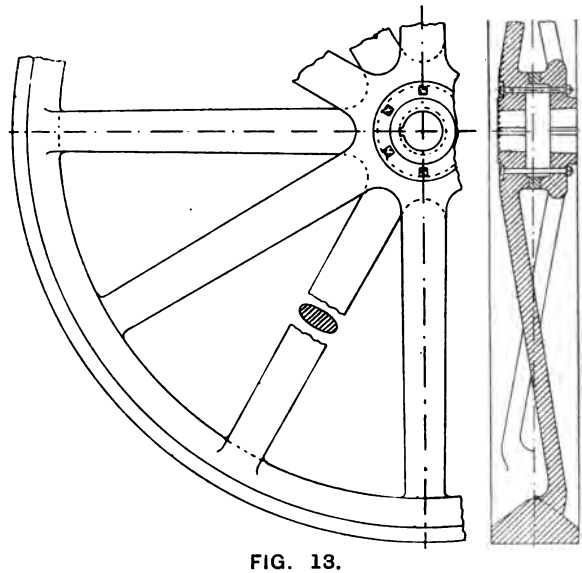


FIG. 13.

by the E. P. Allis Co. The special object of the design is to relieve the wheel of shrinkage strains in cooling. The comparatively large number of arms and the deep rim section permit of high speeds with safety. The arms are arranged diagonally to pass from one side of the rim to the opposite end of the hub. When casting, the hub is in two pieces, the central portion being vacant; after cooling, this central space is filled by pouring in molten iron. In the mould the ends of the hub are separated by a core $\frac{5}{8}$ inch thick, but the shrinking on cooling compresses the arm and increases this space to about $1\frac{1}{2}$ inches, The hub ends are finally fastened together with bolts. These wheels are made up to 10 feet diameter, and of weights up to 12,000 pounds. They are regularly driven at

speeds of 10,000 feet per minute, in some instances up to 12,000 feet per minute. About 300 of them are in use and not one has yet given way. Hinkley's method of avoiding cooling strains is, in the Author's opinion, much better than that in common use here, viz., casting the boss split while the rim is complete, and then shrinking a pair of steel rings round the boss to keep the parts together.

Flywheel with Rim and Web-plates of Mild Steel.—Fig. 14 shows a built up wheel which has been used in some electric tramway stations in America (see Proc. Inst. Mech. Engineers,

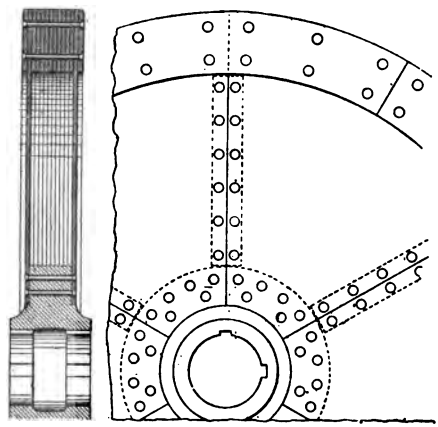


FIG. 14.

Feb. 1898). It has a cast iron hub to which segmental web plates are rivetted. The rim is built up of a number of plates rivetted together as shown clearly in the section.

Flywheel with Cast-iron Arms and Central Run Segments and Rim Plates of Mild Steel.—Fig. 15 illustrates a flywheel now being used by the E. P. Allis Co. for electric traction power plants. The hub is of cast iron, the arms and central rim segments of cast steel, and the rim of steel plates. The rim plates break joint effectually, and at their weakest joint give $\frac{7}{8}$ths of the maximum strength. The steel rim plates serve also

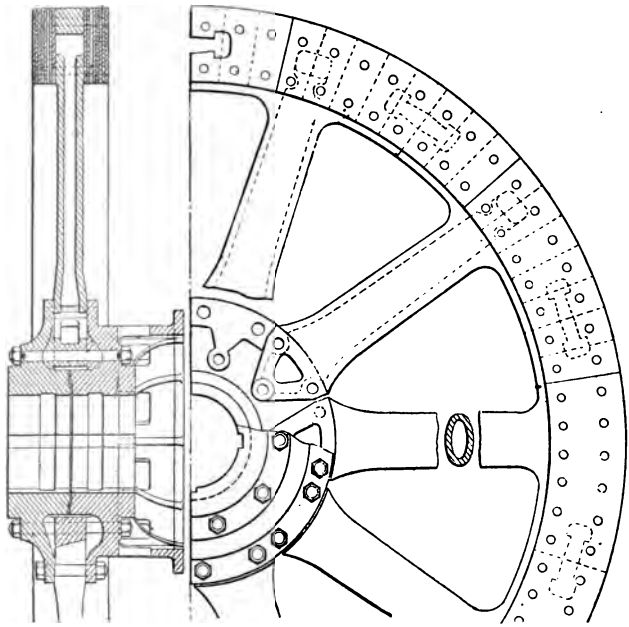


FIG. 15.

to reinforce the joints in the cast steel rim segments, each of which is attached to the end of an arm. The wheel is 28 feet diameter and weighs 150 tons.

Flywheel with Rim and Boss of Cast Iron or Cast Steel, and Tangent Spokes of Mild Steel.—Fig. 16 illustrates a flywheel designed by the author. The illustration is from a photograph of two wheels sent to Prof. Benjamin, Cleveland, Ohio, to be tested to destruction, and Fig. 17 shows the manner in which the wheel broke up. In the design of this wheel there are a number of distinct features embodied. It has numerous spokes instead of a comparatively small number of heavy arms, so that the unsupported length of rim is small, and bending stresses are reduced to a minimum. Another important feature is that in building the wheel an initial tension is put on each spoke by

FIG. 16.

FIG. 17.

screwing up the nuts at the ends, and an initial circumferential compression is thereby put upon the rim. This initial compression on the rim can easily be made great enough to exceed the hoop tension due to centrifugal force when the wheel is running, so that when running at normal speed the rim stresses may be small. A third feature is the tangent spokes; direct spokes of slender rod would be utterly unsuitable on account of their want of circumferential rigidity. A fourth feature is the method of fastening the spokes to the hub by frictional grip alone. The spokes are made in pairs, the middle of each pair is wrapped about half a turn round the hub and lies in a spiral groove. The sides of the groove are inclined at a very small angle, so that any desired amount of wedging action can be obtained. A fifth feature is the perfect freedom of the rim from cooling strains. The rim is practically uninterrupted, and therefore cools uniformly; it is merely of smaller diameter when cooled than when poured.

A drawing of a flywheel 10 feet diameter on this principle is given in the volume of the Proc. of the Inst. Mech. Engineers above referred to. The flywheel was placed on a gas engine at Sheffield, but was taken off, as it was found that being overhung from the bearing the support was not rigid enough.

FURTHER POSSIBLE ADVANCES.

Gas Engine Flywheels.—The type of flywheel shown in Fig. 16 is eminently suitable for gas engines. The rim would be of cast iron, and as it leaves the sand very true, it need not necessarily be turned on its outer surface. The spokes are lighter than ordinary cast iron arms, and thus a saving of dead weight is effected, the arms not contributing much to the storage of energy. It is easily built, and trued like a bicycle wheel. It should not cost much, if anything, more than a solid

cast iron wheel of the same diameter; where it is possible to slightly increase the flywheel diameter without inconvenience it should cost less.

Rope-driving Pulleys.—It is with fear and trembling that I breathe the suggestion to an audience of Manchester engineers that rope-driving flywheels and pulleys, such outstanding features of Lancashire cotton mill engineering, are capable of improvement by a radical change of design. The tremendous masses found in rope driving flywheels are not required for the regulation of the engine speed during each revolution, when the load is steady. The flywheel power required for regulation under a fluctuating load would be obtained more cheaply by having flywheels of large diameter on the second motion shaft (Fig. 18), such flywheels to be built with cast steel rims and numerous tangent spokes on my system (Fig. 16), to run at speeds 200-300 feet per second, with a corresponding reduction of their dead weight to about one-fourth to one-eighth the present

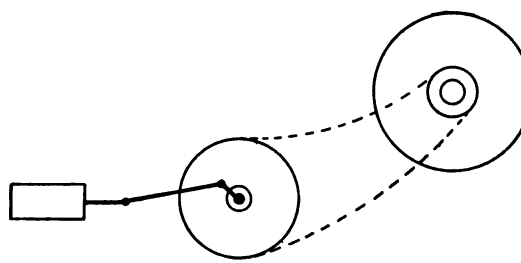


FIG. 18.

value. The wheels of the main drives should be as light as possible. But as the smallest diameter is determined by the condition of durability of the ropes, this cannot be reduced much, if anything, below present practice. To lighten the wheels appreciably they would have to be made of wood. Wheel rims up to 12 or 15 feet diameter would be finally in one piece, somewhat like a laminated wood rim for a bicycle. The spokes would preferably

be tangent steel spokes; although I have made successfully small belt pulleys with wooden tangent spokes. Such wooden rope-driving pulley would possibly weigh only one half to one-fourth an equally large cast iron pulley; its rim thickness would be much greater. The only difficulty in the way is the manufacturing one, there being no plant in this country (to my knowledge) capable of turning out a satisfactory job of such a pulley.

Electric Traction Flywheels, made on my system (Fig. 16) might safely run at rim speeds of 300-400 feet per second, the rims being of cast steel, the spokes of high tension steel. The 100 ton, and 150 ton wheels, clumsy embodiments of mere brute force, would then disappear.

Fly-rod.—This paper has been up to the present point devoted to *wheels*, but if it be desired to store the greatest possible quantity of kinetic energy per unit of dead weight, I am of opinion that a wheel is not the best form of apparatus. Fig. 19 shews diagramatically a fly-rod, consisting of one prismatic bar, round or square, to the middle of which a pair of

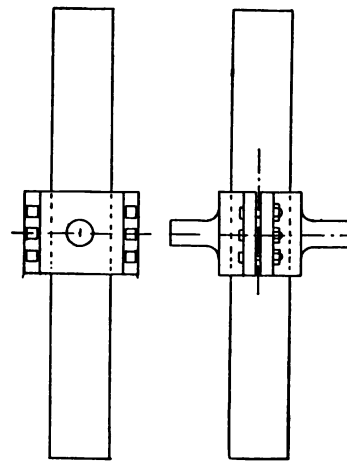


FIG. 19.

short shafts are clamped. If this is rapidly rotated, the greatest stress produced is a tension at the middle, there being no complications by bending of parts. A speed of the extremity of 1,200 feet per second would produce a tensile stress of 33·2 tons per square inch. A speed of 2,400 feet per second would produce a stress of 133 tons per square inch, which *might* be resisted by using a bunch of piano wire; the energy stored per ton weight would then be 30,000 foot-tons. I have not patented the invention, nor do I wish to experiment with the apparatus at or near its safe limit of speed.

DISCUSSION.

Mr. Charles Day said that in dealing with rope-driving flywheels, the author had overlooked several points. The first point was that the best speed at which it had been found desirable to drive ropes corresponded practically to the best speed for the normal construction of cast iron wheels, so that it suited them to put big fly wheels on their slow speed engines. Secondly, assuming they had to put big wheels on, he thought the present construction much cheaper than the author's plan, and it had proved itself to be a very satisfactory one. Turning to the suggestion of putting the flywheels on second motion shafts, he thought that the author's idea was utterly wrong. A regular drive of ropes was wanted, not an irregular one, and any engineer with much experience in connection with very long rope drives, knew the desirability of extreme steadiness of drive, otherwise they would have the ropes jumping out of their grooves, and other troubles, such as would, he thought, accompany the plan suggested by the author. Flywheels should be on the engine shafts so as to at once take up any irregularity of turning moment.

In the first paragraph on engines running under variable loads, the author said that, in a certain case, the flywheel had to be designed to store "practically almost" half the power developed by the engine during "several revolutions." That was very vague indeed. "Several" might mean two, three, or four revolutions, or 20 or 30, so that the statement was not worth much. Again, he thought it was a wrong expression to say that energy stored should be measured by the work done in revolutions. Where energy was put into a flywheel to give the governor time to act, the energy in the wheel should be so many seconds work done by the engine,—not so many revolutions. A high speed engine would require the same energy in the flywheel as a slow speed engine, from the point of view of giving the governor time to act.

The diagram, Fig. 6, was interesting, and it would pay to apply it to many cases, but a very important factor omitted was the time element. It omitted the time taken by the governor to change its position. That would modify the diagram, though it would perhaps be difficult to apply.

With regard to bending stresses on the rim, the formula given was based on something which did not exist at all,—a wheel with free joints. Assuming the joints to have some degree of rigidity, the formula would be greatly altered. As to the illustrations of wheels designed for fairly high peripheral speeds, it was not necessary to go to America for examples. The Allis wheel, shown on Fig. 15, had a not altogether bad connection. He had examined several wheels of that kind in America, and as the bolts were put in "shear" with a constantly changing direction of stress it was to be expected that they would work slack. That, he found, was actually the case.

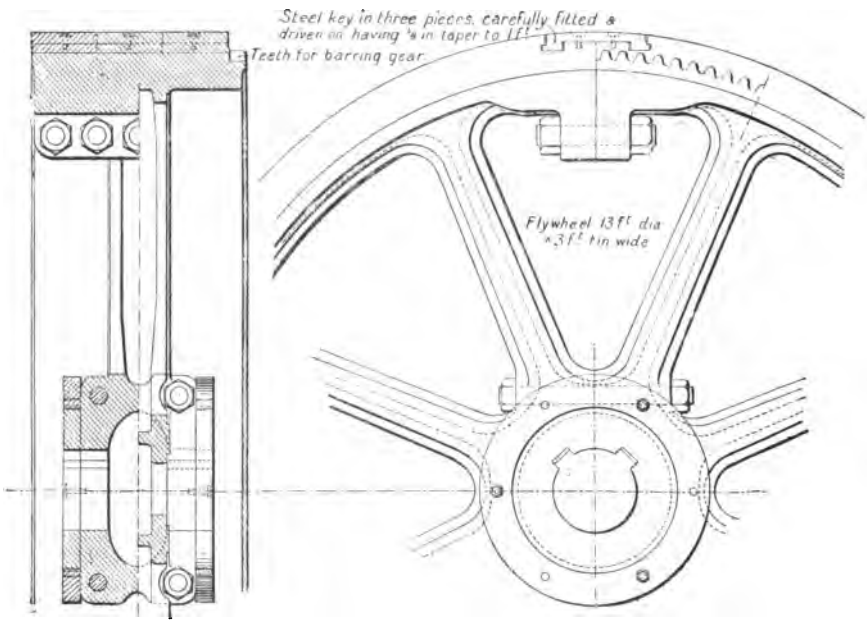
With respect to the wheel shown in Fig. 14, the sides were fairly thin plates. If the shaft had any lateral movement, as they liked to have,—at any rate in mill practice, or wherever

it was practicable—that very heavy wheel would oscillate; it lacked stiffness laterally. In describing his own wheel, the author stated that initial tension was put on the spokes. He did not know whether the author intended that as a claim, but there had been many wheels built in England with initial tension on the spokes. Messrs. Ferranti's had adopted it for quite a number of years. One design, of which they had made a fair number, was a simple circular cast ring, absolutely without joints; then a steel boss was put on to the shaft, and the ring was simply bolted to the boss; the bolts forming the arms, and were screwed into the central steel boss. They were screwed up tight; and then warmed and tightened up again so as to put actual initial compression on the rim, so that at normal speeds the tension was almost removed from the rim. Such special construction, to his mind, did not apply at all for rope driving, but when dealing with dynamos they had another condition. They could have practically any surface speed they liked, and therefore this construction was adopted by Messrs. Ferranti's, to suit alternators.

Mr. James Atkinson said he would like to make a few observations with regard to fly-wheels, in connection with gas engines. The construction of fly-wheels for electric light gas engines had been a very important matter for consideration. Speaking of the practice of Messrs. Crossley Bros. Ltd., they had to make their engines practically standard engines. They could not afford to make one size of flywheel for one engine, and another for another engine of the same size. That being so, they were restricted in peripheral speed to practically something like 90 feet per second, and so long as the engines were small they could get all the fly-wheel power they wanted by means of wheels 8ft. or 9ft. diameter. As, however, engines increased in power, and also increased in stroke, they had to keep piston

speeds to reasonable limits and reduce the revolutions of the engine, to get the proper peripheral speed, they had to put up the diameters of the fly-wheels. These fly-wheels had, as they knew, to be sent from one end of the country to another, and they could only practically send a 9ft. fly-wheel by train; it, therefore, became necessary to make fly-wheels in more pieces than one.

The question then arose as to what was the best method of making the joint in such fly-wheels. After very considerable thought on the matter they solved the difficulty very satisfactorily by an invention of Mr. Wm. Crossley's, which was illustrated by a diagram displayed on the wall. The



wheel was parted right down on the diameter, carefully planed and fitted together, and then, on the top of the junction, steel plates were carefully fitted upon slightly dove-tailed joggles.

The joggle was tapered across the face of the wheel, and the plates were driven on practically in the same way as a key was driven in. This, so far as that portion of the wheel was concerned, made a very satisfactory joint. The same arrangement could be used inside, but it was cheaper to put bolts there. The depth of the rim was thickened, so that practically there was no objection to putting a joint between two spokes; hoops were put on the boss in the ordinary way, and the bolts were put in, as they saw in the diagram.

With regard to the connection between flywheels and governors, this was very different in a gas engine from a steam engine. Gas engines were governed in two ways, viz,, by missing out ignitions altogether, and by modifying the amount of gas per ignition.

Commonly, and in the majority of cases, the best way of doing it was by missing out ignition. To do that, a governor had not to run the full range of its sleeve as in a steam engine. The governing line on a gas engine properly constructed was a hair line, and could be made very sensitive indeed,—in fact, so sensitive, that with a reasonably good electric light gas engine, with proper fly-wheels, they could throw the belt off the dynamo, and the engine would not run away more than 1½ to 2 per cent. In the other method of governing, and the one they principally adopted for electric lighting, they governed by varying the amount of gas per ignition; this was done by what was termed a "step die." Instead of a hair line, to govern on, they governed on the width of a notch, probably ⅛in. As the governor worked in this way they could make them practically isochronous. This consideration would very much modify the diagrams shown in Fig. 6. He ought to mention that the governor had scarcely anything to do, it only moved a very light part, a few ounces in weight, consequently they could make it very free, and there was practically no difference

between the rising and the falling line, bringing the lines G_1G_1 and G_2G_2 into the dotted position of GG. The flywheel line which Mr. Sharp had put on the diagram was a very interesting way of illustrating the effect of a heavy flywheel. They had to make flywheels very much heavier than for steam engines, and quite realised the effect of this in the governing.

With regard to the hoop tension in a flywheel this could be calculated by taking the speed of the centre of gravity of the rim in feet per second, squaring it, and dividing the square by 10, the result would be the strain per square inch, if the material were cast-iron, this was correct within 8 per cent. Fly-wheels for gas engines had commonly—as they were compelled to make them—very heavy rims, and the depth of the rim was large in proportion to the diameter of the wheel, much greater than was usual in steam engine practice, and the bending moment between the arms was very much less than it would be if the depth of the rim were proportionately less, so that they could not apply such extreme figures as those on pages 206 and 207 to gas engines.

An even better way of making flywheels that contained a larger amount of energy than any mentioned in the paper, was to make a plain cast-iron wheel with, say, trough section of rim, and simply wind it with wire. Such wheels had been made in America very successfully, and would be about as cheap as it was possible to make a good wheel. The great objection to it, and one which had really prevented Messrs. Crossley adopting it, was that they could not take it in pieces, and put it together again, without a great deal of trouble; but the method of constructing it was one whereby they could make a wheel with any amount of strength in it, probably better than in any other way he knew of.

As to putting a heavy wheel on the second motion shaft, and driving it from the engine with ropes, there were great

difficulties in the way of that kind of driving. If they had a fly-wheel on an engine, and one on the second motion shaft, the relative movements of the two were continually varying, and the ropes would certainly not remain long in their grooves, in an extreme case.

Mr. R. Gregory said he had seen some of the Allis wheels, illustrated in Fig. 15, and the speed of these was 75 revolutions. The arms were fastened to the boss by three bolts, which was cheaper than the method adopted here of bored bosses and turned arms, and the bolts, from what he could hear, did not work loose. The bosses were made in two halves, and the arms went in between the bosses, and did not fit together at all, or touch at the end. If the method was satisfactory, it was a good deal cheaper than our method. The wheels he had seen were running at a very high velocity, so that they provided a good test of the bolts.

Mr. A. L. Mellanby said it would be interesting to have some information respecting the masses of fly-wheels required for various types of engines. It was rather difficult to find out in any text books what was the average value of $\frac{\triangle E}{E}$ for various types of engines. They could find it for a single cylinder engine, within a certain range, and probably for a compound, but he had never yet seen it stated for a triple or quadruple expansion engine. He would ask the author if he had any information as to the relative sizes of flywheels required for the same power of engine whether it were compound, triple, or quadruple expansion, when the question of governing within certain limits had to be considered.

Mr. Sharp, in replying on the discussion, observed that Mr. Day's remarks really amounted to a case of talking about the same things in a different way. He had not meant, in his

paper, to say that the present practice in Lancashire, as to heavy fly-wheels, was wrong; but what he did mean to convey was this,—that in many cases there was a heavy fly-wheel, the mass of which was much greater than was necessary to give the desired steadiness of running. He would be the last person to suggest that the fly-wheel on an engine shaft should be so light as to make pulsations on the rope so great as to be inconvenient. He had purposely got out example No. 1, to illustrate this very point. The engine was a fairly big one—1,000 HP—and they were told by Unwin that if the fluctuations of speed did not exceed 1 in 100, the conditions were satisfactory for driving textile machinery. He was not prepared with the necessary data to say whether that value of the fluctuation was correct, but taking it on that basis they only required a flywheel weighing 4·2 tons. If a rope would drive satisfactorily, without the pulsations becoming inconvenient, with only that variation in the speed of the main fly-wheel, he was sure that in many cases there was more weight than necessary for the requisite steadiness of driving.

If, on the other hand, the weight of the fly-wheel was to be there to govern against variation of load, *i.e.*, not merely to give steadiness during revolution, but for governing under varied load, it would not affect the rope-drive at all, whether the flywheel was on the first or second motion shaft. In such a case he still maintained that it seemed to him more scientific to get the fly-wheel effect from increased speed, and not from mere dead weight. In other words, they must have their main flywheel sufficiently powerful to give steadiness during revolution; but to give the flywheel effect for governing under variable loads, they might have it on the second motion shaft, if otherwise it was convenient.

The statement about fly-wheels for variable loads, described by Mr. Day as "vague," was purposely so. Supposing they

had a very small tramway installation, perhaps with only one or two cars on the system, and only about a mile of tramways, the load might fluctuate from zero to the maximum, very quickly. If, on the other hand, they had a system for a town like Manchester, with several hundred cars, the top of the curve might be of the same shape, but the base line would be very much lower down; so that, in the small installation, the flywheel power must relatively be very much greater than in the large installation.

As to the bending formula being based on conditions that did not exist in practice, he thought he had stated the conditions that existed in practice perfectly. He gave two extreme cases, one in which there was no bending resistance at the joints at all, and then a case where resistance at the joints was perfect. In any actual case of a rim joint the conditions would come somewhere between these two extremes. The constant in the formula for the two extremes did not vary much; it was about $\frac{1}{8}$in. for one, and $\frac{1}{12}$in. for the other, speaking from memory. As to Ferranti's wheel with initial compression on the rim, he was not aware of the fact that they had such a wheel, but he had not meant to suggest for a moment that he was the first to put initial compression on the rim of a fly-wheel.

The joint described by Mr. Atkinson filled the bill admirably; they kept the line of stresses unbroken, whereas with merely bolts inside they would have a very big break in the line of stress. Mr. Atkinson's remarks about governing, and the practical co-incidence of the two lines in the diagram, were very interesting, While the gas engine was much worse off than the steam engine for steadiness during revolution, he thought they were practically identical as regards governing under variable loads. At least, the difference, if any, was not very great. The formula for hoop tension was interesting, and corresponded with that given in formula (3) in the paper. As Mr. Atkinson

had observed, the deeper the section of the flywheel rim the less was the bending stress. In fact, they might take it for granted that the rectangular section was the ideal one for wood, but the I section the ideal one for iron. With regard to the cheapness of the American wheel mentioned by Mr. Atkinson, he scarcely thought steel wire of small diameter could be obtained as cheaply as cast iron, and certainly the construction of the wheel he had designed gave sufficient strength for any rim speeds that would be required, for the next few years at any rate.

The Allis wheel shown in Fig. 15, which was 28ft. diamater, would give a rim speed of 104ft. per second, at 75 revolutions per minute. He was sure the cost made it prohibitive. As to the method of fashioning the arms, he should think it very good ; it ought to be slightly better than the Lancashire style, presuming the depth of the hub was the same in the two cases, and there was the advantage that they had fewer joints. He was afraid he could not supply Mr. Mellanby with the information he required. In any particular case, however, he thought it would be a very easy matter to get hold of some indicator diagrams and roughly sketch out what the value would be. In such cases they need not work very accurately, but merely a rough hand sketch would enable one to arrive at an estimate within, say, 5 or 10 per cent. of the quantities involved.

Mr. Atkinson, in moving a vote of thanks to the author, said he had given a very interesting paper on a most interesting subject. The difficulties in the way of introducing a wheel like that of Mr. Sharp's, in this country, were very great. People were bad to move, as they had their own established ways of doing things, and even when they were willing to introduce a novelty they had to consider the whims of customers. Mr.

Sharp's wheel, however, had many essential advantages, and as he kept "hammering away" at it, he would, no doubt, eventually be successful.

Mr. HANS RENOLD, in seconding the motion, observed that they had had a very useful paper. The flywheel, though a very simple element in machine construction, was not understood by many people with whom he came in contact in the course of business. Only the previous week he was in Yorkshire in a bridge-building establishment. They had a very large punching, shearing, and angle-iron cutting machine, capable of shearing a $1\frac{1}{8}$in. plate, punching a $1\frac{3}{8}$in. hole in plates $1\frac{3}{8}$in. thick. On the second motion shaft there were two very large flywheels, 7cwt. each, and this shaft was driven with a chain by an electric motor, which was 8 HP, and had a speed of 900 revolutions. Trouble supervened, owing to the heavy flywheel acting one way, and the armature at 900 revolutions as another flywheel. A kind of cross action between these two flywheels was set up, and, since chain driving formed a positive connection, there was no safety valve left, which with leather belt driving did exist in the form of slipping. The chain, in addition to doing its legitimate work of transmitting power, had also to act as an equaliser. The consequence was that the chain wore away much faster than otherwise it would have done. He was quite astonished in talking with the manager as to the cause, to find how little he had grasped the idea of what a fly-wheel really was for.

In another case, a large steam-engine builder was converting a 400 HP engine from a common slide valve to the Corliss valve system, and putting in new cylinder work. On taking away the old eccentric discs and rods, he found the flywheel was very much out, and the second shaft, driven by a chain, and from which the Corliss valves were actuated, as well as the governor,

gave a very irregular turning motion. Instead of removing the cause by correcting, that is, by balancing the main flywheel itself, a second flywheel of about 5cwt. was put on the second shaft, thus trying with one flywheel to counteract the other. Now surely no man with a true idea that a flywheel is a storer of energy could do such a thing.

Mr. Sharp, in acknowledging the vote of thanks, remarked that there was certainly great difficulty in introducing new things in this country. The manufacturer, he presumed, existed principally to make a profit, and next had to consider his customers' wants. At the same time, he should look a little ahead and remember that it was quite as unwise to lag behind as it was to look too far ahead. He had been hammering away at fly wheels for a number of years. He had made no financial profit out of them, though the balance to the bad was certainly not very much, and this had been more than counterbalanced by the indirect benefits it had brought to him as a professional man.

TESTING THE MAGNETIC QUALITIES OF IRON.

READ SATURDAY, 10TH NOVEMBER, 1900,

BY

Mr. G. JAMES WELLS,

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With the increasing use of the dynamo and electric motor there is a corresponding increase in the use of iron by electric engineers, and the demand has now reached such proportions that many firms have laid down special plant to deal with the peculiar forms required in the manufacture of dynamos. For many years past the engineer has required iron to comply with certain conditions, such as to carry a specified load per unit area, with a given increase in length, to bear bending to a short radius without showing any signs of weakness, &c. These conditions are capable of mechanical proof, inasmuch the load can be put on, and the alteration of length ascertained by direct measurement, consequently the iron manufacturer had comparatively little trouble in comprehending the qualities required, and although the tests have undoubtedly been often stringent, yet by reason of their mechanical character they may be easily checked. Similarly the dynamo builder requires his iron to have certain special qualities in order that he may obtain a certain specified result from the finished machine.

These requirements were different from anything previously required, and the majority of the iron manufacturers found it very difficult at first to grasp exactly what was actually demanded of them, and in consequence in the early days of the industry

very few firms would give any guarantee concerning the magnetic qualities of their iron. This was a very natural result, for man is not yet in possession of an electrical sense, and it is not possible for a novice to see clearly what is the difference between a good and bad quality of iron from the magnetic standpoint without some previous training, much less can he be expected to test it and state its qualities with any degree of confidence. It is the intention of the author to lay before this Association a brief account of some of the methods that have been used by various authorities to determine more or less exactly the magnetic qualities of iron. In order to do this clearly some explanation of the phenomena of magnetism must be given first, so that an idea may be formed of what it is that has to be measured, as well as of the principles that underlie the methods actually made use of in the apparatus employed in the laboratory and factory.

Magnets may be separated into two general classes, in the first the *loadstone* (or *natural* magnet) is placed. Loadstones are rare, although a closely allied ore of iron capable of being acted upon strongly by magnetic forces is found in large quantities in Sweden and other districts, and is in consequence spoken of as magnetic iron ore. The natural magnet may be dismissed as having little if any interest to the practical engineer.

The second class may be sub-divided into two groups, and in the first may be placed *permanent* magnets, usually made of hardened steel, artificially magnetised, and retaining their magnetic properties for a considerable period of time; whilst in the second sub-division may be placed those magnets that lose their magnetic properties immediately the magnetising power is cut off. These latter are always constructed of very soft iron or steel and magnetised by a coil of insulated wire energised by an electric current.

The intensity of the magnetic force varies in different parts of a magnet, and the points where its effects are most strongly exhibited are termed poles. In the common bar magnet the position of the two poles are at the ends, but there may be poles in other positions, and where this is the case they are spoken of as consequent poles. The common bar magnet is shown in Fig. 1, and the ends marked N and S are the poles. This bar

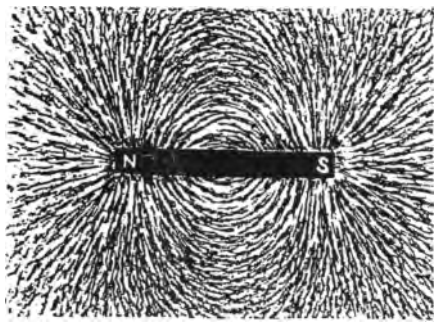


Fig. 1.

when bent into the shape of the letter U is called the horse-shoe magnet, the position of the poles remain unchanged. In dynamos of the bi-polar type the field magnets are of this form.

One of the oldest and best known properties of a magnet is its power of attracting soft iron and holding it indiscriminately, but in the case of other magnets one end only was held, the other end being forced away. Another well known property is that a magnet freely suspended and uninfluenced by any other neighbouring magnets, always points to the North Pole. This power of selection led to the hypothesis of two different kinds of magnetic fluids, and that which accumulated at the end pointing north (commonly spoken of as the north-seeking pole, or more shortly as the north pole) has been termed *positive*,

whilst that at the other pole the *negative* fluid. These older ideas concerning magnetism are interesting because they afford an explanation of the origin of the terms commonly used when speaking or writing of magnetic phenomena, otherwise, it is needless to say, that the conception of a "*magnetic fluid*" has been long since abandoned.

The region of space surrounding a magnet is called the *magnetic field*, and the character of this field is most conveniently shown by means of a small magnet, so suspended as to be free to take up any position when placed in various parts of the field. The position of this exploring needle at any given point will be that its north-seeking end will be drawn towards the south pole of the large magnet (see Fig. 2). Plotting the

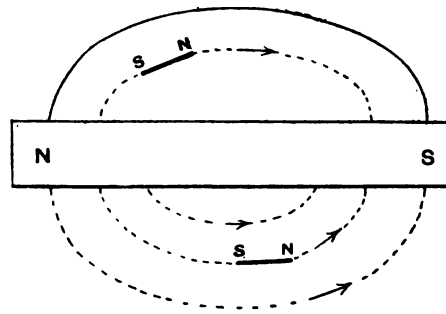


Fig. 2.

position taken up by the needle in various parts of the field it will be found that the successive positions taken up by the needle are tangential to a smooth curve which pass from the north pole to the south pole. These curves are more clearly shown by means of iron filings sprinkled upon a piece of glass placed above a magnet, when a few light taps is all that is necessary to cause the filings to range themselves along these curves. Several illustrations are given in Figs. 1, 3 and 4 of fields so obtained. These curves show only the lines in the

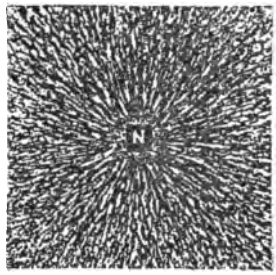


Fig. 3.

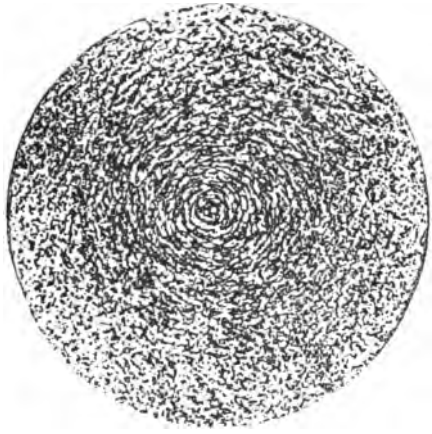


Fig. 4.

plane of the glass, but they must be actually thought of as occupying the whole space surrounding the magnet (Fig. 5).

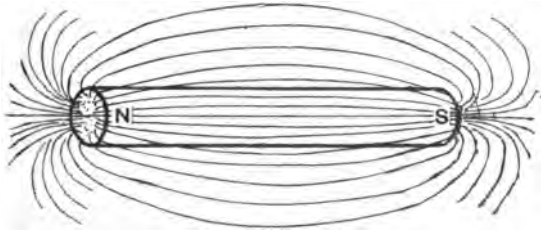


Fig. 5.

The density of the filings roughly show the intensity as well as the direction of the magnetic force at any point in the field, and Faraday gave them a quantitative meaning, so that to-day the intensity of the magnetic force is spoken of as so many lines per unit area. At this stage it is necessary to lay stress upon the real meaning of the phrase *magnetic lines of force*, as at the commencement one is apt to associate a material meaning to the word line, and to think of a magnetic field as a path obstructed with a network of cobwebs, through which an elephant (a non-magnetic body) could pass quite unconsciously, whilst the flies (iron filings) would be arrested and glued to positions which would show the line of flight. These lines must be thought of only as a convenient method of representing the direction of magnetic force in a magnetic field. They form closed loops, part of each loop passes externally through space and returns through the interior of the magnet.

The unit quantity of magnetism at any magnetic pole is defined (internationally) as being such that it will repel a similar quantity at a distance of one centimetre in air with a force of one dyne.

The intensity of a magnetic field at any point is measured by the force with which it acts upon a unit magnetic pole. The usual convention adopted is to let each magnetic line of force to represent a force of one dyne, *i.e.*, a unit pole, so that the number of lines per square centimetre becomes the method of stating the strength of a magnetic field at any point. But as the surface of a sphere of one centimetre radius $= 4\pi$ sq. cm., 4π lines must radiate from unit pole. The symbol generally used for magnetic force is H.

A magnetic field is said to be uniform when the lines of force are uniform in direction and magnitude.

In 1820 Oersted noticed that a current of electricity flowing in a wire disturbed a compass needle that was near to it, and

then speedily followed from the researches of Ampere, Arago, Davy, Faraday, &c., the full demonstration of the magnetic properties of an electric current. Summing up these properties briefly, it may be shown with the help of some iron filings (see Fig. 4) that a wire carrying a current sets up a magnetic field, and that the lines are circular in shape, with the wire at the centre. Fig. 6 shows the direction of the current and the direction of the magnetic whorls produced.

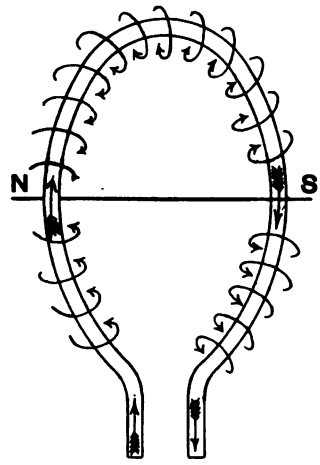


Fig. 6.

If a coil of wire having many turns be traversed by an electric current then the magnetic effect is considerable, and the whole coil behaves, if freely mounted, exactly as a magnet would under similar circumstances. Fig. 7 shows a coil, the arrows indicating the direction of current flow, and the magnetic lines of forces are also shown, the lines entering and leaving the coils at the ends. Such a coil as here described is called a solenoid.

Magneto-motive-force is the name given to the magnetising force of the electric current flowing in a coil.

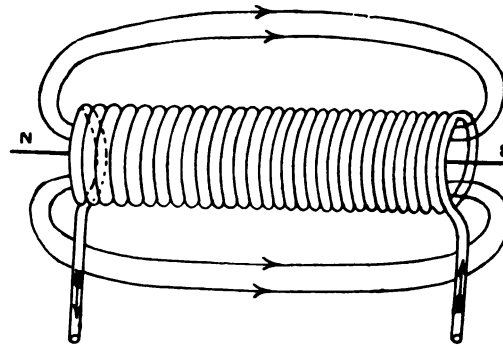


Fig. 7.

Let n = no of spirals in the coil,

c = the current in amperes,

l = the length of the coil,

H = the intensity of the magnetising force in G.G.S. lines,

then

$$\text{Magneto-motive-force} = \text{H} = \frac{4\,\pi\,n\,c}{10\,l}; \quad - \quad - \quad (1)$$

$$= 1{\cdot}257\ n\ c \text{ per centimetre of length} \quad - \quad (2)$$

and this is usually spoken of as being

$$= 1{\cdot}257 \times (\text{Ampere-turns})\ ; \quad (3)$$

In practice the usual problem to be solved is to find the number of ampere-turns to give H lines per sq. centimetre, and the more useful form of the above formula is

$$\text{Ampere-turns per centimetre} = 0{\cdot}8\ \text{H}\ ; \quad - \quad (4)$$

or if the English inch be used as the unit of measurement, then

$$\text{Ampere-turns per inch} = 0{\cdot}313\ \text{H}'' \quad - \quad (4a)$$

These formulæ are true only for air, as the medium surrounding the solenoid.

If a piece of soft iron be inserted within the coil, then the iron becomes strongly magnetic, because the iron is a good conductor and concentrates the magnetic lines within it, so that

the field strength is considerably increased and consequently the magnetic power is correspondingly augmented. The symbol B is used to denote the density per unit area, and is connected with H by the formula :—

$$\mu H = B \text{ ; or } \mu = \frac{B}{H}; \quad - \quad - \quad (5)$$

The co-efficient μ is called the "co-efficient of induction" or permeability. The value of μ is always a positive quantity, for magnetic bodies such as iron it may equal 8,000 under certain conditions (see tables in appendix).

When soft iron is the material used for the core of the solenoid, then the iron only exhibits magnetic properties whilst the current is flowing in the coil, but if hard steel be used then it retains its magnetism after the current is interrupted. The old writers on magnetism considered this result to be due to "coercive force," which was of the nature of a molecular frictional resistance opposing the action of the magnetising force, and also resisting the loss of magnetism when the excitation was removed. The greater the coercive force the greater the permanent magnetism. Permanent magnets must be made of "hardened" steel, whilst temporary magnets must be made of the softest brands of iron or steel. When the coil surrounds a core of soft iron it is called an electro-magnet.

The law of the magnetic circuit may, stated in a similar manner to Ohm's law of the electric circuit for steady currents :

$$\frac{\text{Electro-motive force}}{\text{Resistance of circuit}} = \text{current};$$

$$\frac{\text{Magneto-motive-force}}{\text{Reluctance}} = \text{magnetic flux.} \quad - \quad (6)$$

The magnetic reluctance is represented by the formula

$$\frac{l}{\mu a};$$

where l = length, and a = area of path of the lines of force.

Magnetic flux = Z = Ba, hence equation (6) is written symbolically, thus

$$Z = \frac{\frac{4\ \pi\ n\ c}{10}}{\Sigma\left(\frac{l}{\mu\ a}\right)} \quad - \quad - \quad - \quad (7)$$

the reluctance is usually expressed as a sum, because the circuit is usually a complex structure, having sections differing in length, cross sectional area. and material.

The most useful form of formula (7) is

$$\text{Ampere-turns per centimetre} = 0{\cdot}8\ \mathrm{B}\,a\ \Sigma\left(\frac{l}{\mu\ a}\right); \quad (8)$$

or if the *inch* be used instead of the *centimetre*, then

$$\text{Ampere-turns per inch} = 0{\cdot}313\ \mathrm{B}''\,a\ \Sigma\left(\frac{l}{\mu\ a}\right); \quad - \quad (8a)$$

The force of attraction exerted by a magnet is given by the formula

$$\mathrm{P} = \frac{4{\cdot}057\ \mathrm{B}^2}{10^8}\text{kilogrammes per sq. centimetre.} \quad - \quad (8)$$

or $$\mathrm{P} = \frac{1{\cdot}387\ \mathrm{B}''^2}{10^8}\text{pounds per sq. inch} \quad - \quad - \quad (9a)$$

Just as an electric current flowing in a wire produces a magnetic field round that wire, so does the formation of a magnetic field near a wire forming part of a closed circuit cause a current to flow in that circuit. This can be easily shown to be true by a simple experiment of inserting a magnet within a coil and then withdrawing it again, when the galvanometer needle will be deflected in opposite directions by each motion. It will be noticed in making this experiment that the galvanometer only indicates a momentary disturbance, and that the current is only a very small one. The electro-motive force produced is proportional to the *rate* at which the "lines of force" are threaded by the coil, the greater the rapidity with which the magnet is inserted into or withdrawn from the coil, the greater is the voltage induced. If the coil be moved in a

magnetic field so that the number of lines enclosed remains constant, then the E.M.F. induced in the closed circuit is zero.

Let V = the potential difference in volts generated.

B = the number of lines per sq. cm.

α = the area of cross section of coil in sq. cm.

Z = B α = the total number of lines passing through the circuit at any instant.

Then

$$\text{E.M.F.} = \frac{d\,Z}{d\,t}$$

$$\text{or} \qquad V = \frac{d\,Z}{d\,t}\,10^{-8};$$

In practice a solenoid is used containing N turns, and arrangements are so made that the fraction of time in which B is being reduced to zero is as small as possible, and the E.M.F. generated will be then a maximum.

Having briefly described the intimate relationship between the magnetic field and the electric current, it will be apparent that it is of the utmost importance to know the exact value of μ for the iron from which any electrical apparatus has to be made, and attention must now be given to the methods which have been successfully used to ascertain experimentally the magnetic character of any example.

There are four experimental methods :—

(*a*) Magnetometric Methods.

(*b*) Balance Methods.

(*c*) Induction Methods.

(*d*) Traction Methods.

The first two of these are of little practical importance, and cannot be compared with the others. The Author does not remember any instance of their use outside the laboratory.

INDUCTIVE METHODS.

There are several ways in which this method has been carried out, but they all depend upon the production of a momentary

current in an exploring coil which surrounds the sample of the iron to be tested; the magnetising force being produced by another coil having a known number of turns in which a known current is flowing.

Ring Method.—In this the sample of iron is in the form of a ring over which are wound two independent coils, *i.e.* the exploring coil and magnetising coil. This form has been used by Stoleton, Rowland, Bosanquet, Ewing and Hopkinson. In Fig. 8 is shown in diagram form the arrangement of the circuits, and will serve as an example of this method, and how a series of observations may be made.

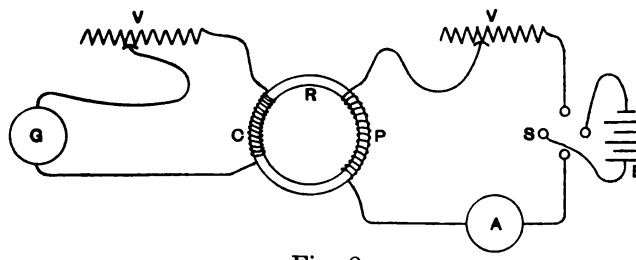


Fig. 8.

B represents the battery supplying the magnetising current; V is a variable resistance to allow the current to be varied from zero up to the maximum current permissible, A is an ampere meter; and S is a switch for completing and interrupting, or reversing the magnetising current. In the secondary circuit V represents the variable resistance used to adjust the reading of the Ballistic Galvanometer G; and sometimes there is an arrangement of magnet and coil placed in this circuit to bring the needle of the galvanometer to rest between observations and so save time.

The method of making a test is to adjust the resistance V to allow a small current to flow through the coil, then to suddenly reverse, and then to reverse back again. Each sudden change in the magnetic condition of the ring produces a momentary current in the exploring coil, which is measured by observing

the magnitude of the deflection of the galvanometer needle. Only two observations are needed which must be simultaneously made, *i.e.*, the value of the magnetising current C indicated by the Ampere meter and the throw of the needle, when the circuit is reversed by the switch S.

The number of coils (N) wound round the ring being known, the magnitude of the magnetising force (H) is calculated by means of formula (1) where l is the mean circumference of the ring.

The value of B is proportional to the deflection of the galvanometer, and for this purpose the galvanometer must be calibrated and care taken that the surrounding magnetic field is at least constant during the times that the experiments last. This question of the galvanometer constant is referred to in the appendix, where one method of calibration is given.

The simultaneous values of B and H should be plotted in the form of a curve, an example is shown in Fig. 9.

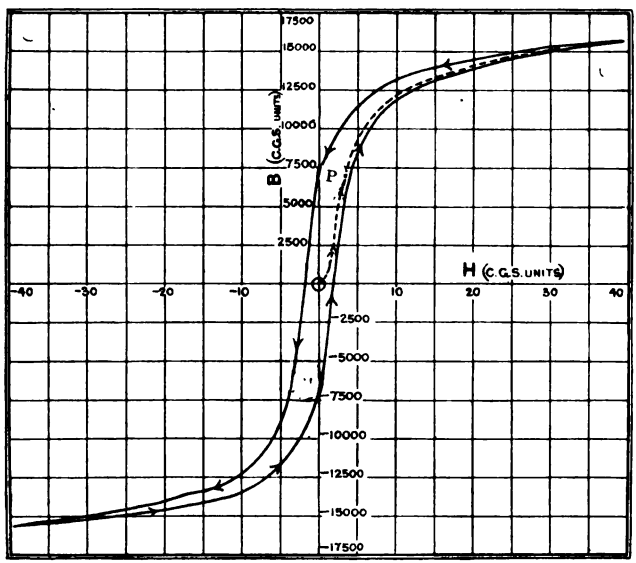


Fig. 9.

In Fig. 10 is shown the path of the lines in an iron ring under two conditions of winding; the left hand ring is wound so that the coil covers a sector only as shown, whilst the right

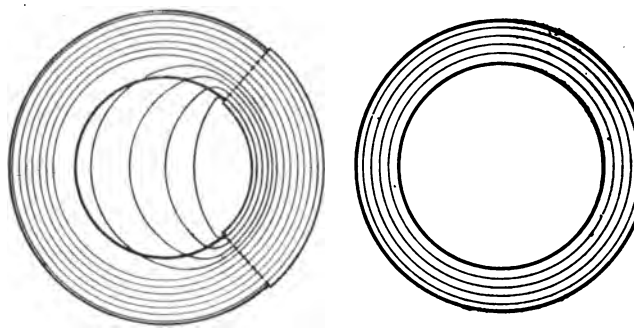


Fig. 10.

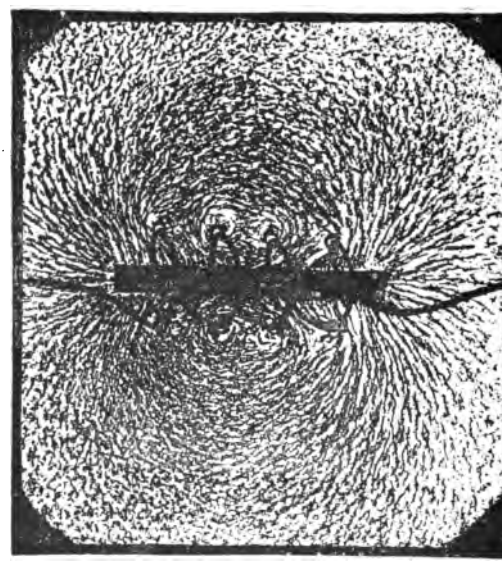


Fig. 10A.

hand ring is so wound that the coils form an even layer over its whole surface. It will be noticed that the path is entirely within the iron when the coil is evenly spread over the whole ring

but if the ring be wound unsymmetrically then there may be serious errors introduced by reason of leakage of some of the lines through the air. Mr. Vignoles states that he found in the case of a ring about four inches across, with the primary coil wound only half round, that this leakage amounted to about 10%. When the secondary coil is much larger in section than the iron, then an error due to air induction is introduced, but this is only important when the permeability of the iron is very low. Fig. 10A shows the distribution of the magnetic lines in a field, produced by inserting a bar of iron into a helix through which a current is flowing.

A variation on this method is that devised by Messrs. Evershed & Vignoles, described in a paper read by the latter before the City and Guilds of London Institute, Old Student's Association, on May 13th, 1891, and published in extenso in the *Electrician* of May 15th, 22nd, and 29th, 1891. The experiments were carried out in a dynamo factory during working hours, and were in consequence subject to considerable vibration, with serious variations in the intensity of the earth's magnetic field.

A ring is prepared from the plates of a convenient size and sectional area, and overwound with three independent coils, two of which are the primaries P and P_1, and one the secondary (S) in connection with the Ballastic galvanometer. In the diagram (Fig. 11) these coils are shown as occupying only a small portion of the ring surface for the sake of clearness, but they actually occupy the whole surface of the ring. One of the primary coils contain just double the number of turns of the other, the object being to obtain just twice the number of ampere-turns in one primary, as compared with the other, when the maximum currents are being used, The secondary coil has just the requisite number of turns necessary to produce suitable deflections of the galvanometer.

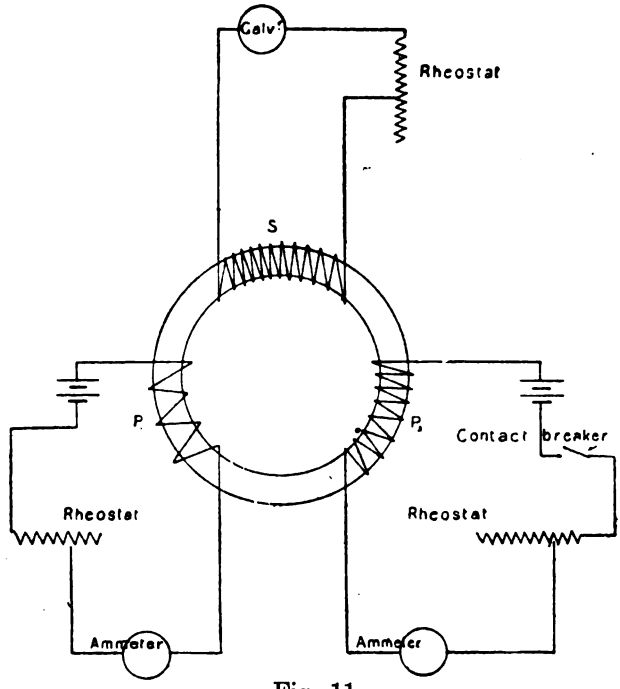


Fig. 11.

Messrs. Evershed & Vignoles kept before them the necessity of making their experiments under conditions that were as nearly as possible similar in character to those obtaining in actual work. Take for example a transformer in which the cycle of magnetisation is repeated always in one direction, that is first a maximum positive value, then to a maximum negative value, back again to the maximum positive value again. Fig. 11 shows how this was done. The primary circuit P_1 includes a suitable source of current, an ammeter to show continuously the amount of current passing, and an adjustable resistance to keep the current steady during the experiment. During the experiments a current of constant strength is continuously flowing in this coil, which keeps the iron at the maximum negative value — O in Fig. 12 when acting alone. The other

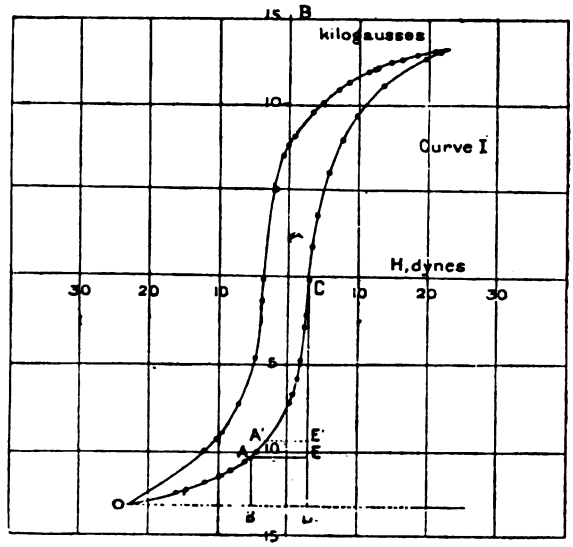


Fig. 12.

primary coil P_2 is also in circuit with an ammeter, a source of current and adjustable resistance for varying the current strength, and a contact breaker. The current flows in the coil P_2 in an opposite direction to that in P_1, so that by inserting suitable resistance in the circuit the iron can be easily carried to any point between $-$ O and $+$ O, the maximum negative and positive values.

The method of making the experiments adopted was to pass a current of 10 amperes through P_1, which was maintained accurately until the cycle was obtained. In the second coil P_2 there were twice the number of turns, and by passing a current of 10 amperes the iron was carried right up to $+$ O, and upon breaking the circuit back again to $-$O. Next a small current was passed through P_2, and the deflection obtained when the circuit was broken noted, this gave an intermediate point, say A. Then the iron is carried up to $+$ O and back again by making and breaking the current of 10 amperes in P_2,

as many observations being made as may be necessary to obtain the cycle.

Instead of a ring a long bar of iron may be used. This is known as the bar method, and has been used by Rowland, Bosanquet, and Ewing. In order to get rid of the errors due to end effects Ewing used bars, whose length exceeded their diameter more than 100 times, but unless very small diameters are used the length of the samples becomes very great. If the bar was ½in. diameter its length would approach 5ft., and as this length may be considered a minimum it is easy to see that compared with the ring methods it is a cumbrous variant.

Dr. Hopkinson introduced the "divided bar" method, and the results that he obtained, see Fig. 24, have been used very largely by electrical engineers ever since his paper was published.

The apparatus is shown in Fig. 13 and similarly to the ring

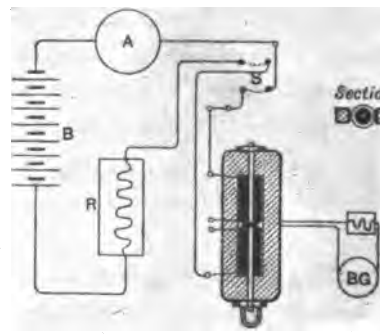


Fig. 13.

method consists of a battery B, a regulating resistance R, an Amperemeter A, a switch for reversing and interrupting the magnetising current, an exploring coil in circuit with a ballistic galvanometer B G. The apparatus consists of a block of annealed wrought iron about 18 inches long, 6½ inches wide, and 2 inches deep, out of the middle of which is cut a rectangular

slot to receive the magnetising coils. The samples of iron to be tested were rods 12·65 millimetres in diameter, carefully turned true and slide in through holes in the ends of the iron block. These two rods meet in the centre of the slot, their ends being carefully trued so as to make a good contact. One rod is fixed firmly, whilst the other has a handle attached so that it can be withdrawn. The magnetising coil is wound on two bobbins, and when they are placed in the slot there is a space between them in which was placed the exploring coil. This exploring coil was wound upon an ivory bobbin, the end of the moveable rod passing through its centre. The bobbin was attached to an indiarubber spring, so that when the moveable rod is withdrawn the bobbin jumps entirely out of the magnetic field. The exploring coil had 350 turns of very fine wire and the two magnetising coils had 2,008 turns.

Dr. Hopkinson, in this research, examined 35 different samples of iron of known chemical composition, including a soft

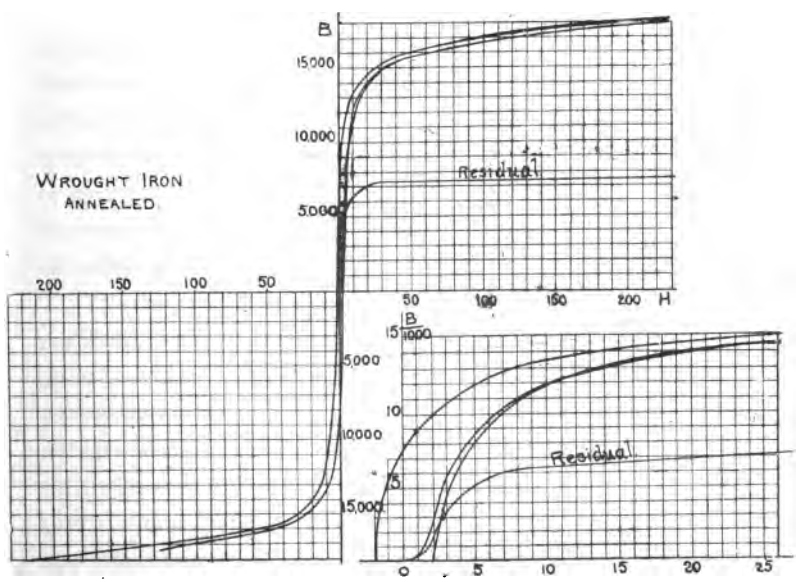


Fig. 14.

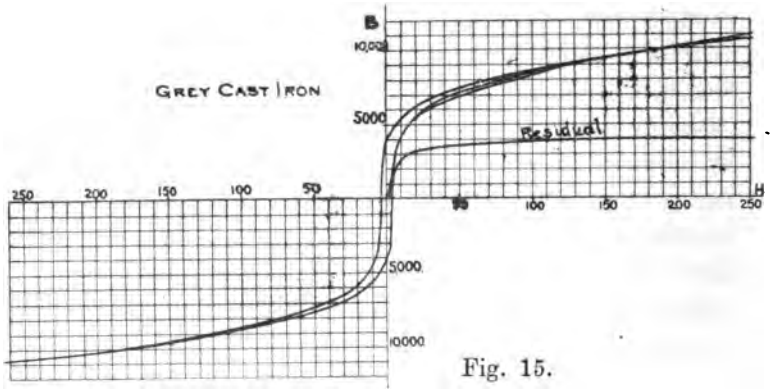


Fig. 15.

wrought iron and a grey cast iron. These are shown by the curves in Figs. 14 and 15, and these are the basis of the majority of tables that are given in the text books dealing with the subject.

TRACTION METHODS.

Mr. Shelford Bidwell used a ring of very soft charcoal iron 6·4 millimetres diameter, and about 8 centimetres external diameter, it was sawn in half, the cuts being carefully trued so as to fit together as closely as possible. The two halves were wound with a coil having a total of 1929 turns of insulated copper wire, and when they were brought together formed a continuous iron ring. When the exciting current was flowing the two parts attracted each other, and the force required to separate them was measured, and the B calculated by means of formula (9), whilst the value of H was obtained from the product of the amperes and turns by means of formula (1).

In another set of experiments Mr. Bidwell used a divided bar, one end of each portion having a hook, one of which was hung upon an overhead support and to the other hook was hung a scale-pan. The greatest weight which could be placed in the scale-pan without separating the bars was then observed.

Dr. Sylvanus Thompson has devised a method which is very easily operated, and is another form of the bar method. In a

block of iron 12in. long, 6½in. wide, and 3in. deep, a slot is cut to receive the exciting coil, which was 13·64 centimetres long and was wound with 371 turns of wire. This number of turns when a current of one ampere was passing gave a magnetising force of H=34·18, and as the wire was able to carry 30 amperes a value of H=1,000 could be obtained. The sample of iron to be tested is in the form of a rod about a foot long, having one end carefully faced up so as to bed upon the iron block, passing through a hole bored for that purpose at the other end. Fig. 16

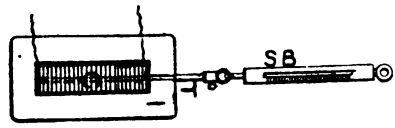


Fig. 16.

shows these arrangements complete with a spring balance to measure the pull necessary to separate the bar from the block.

The Ayrton and Mather Apparatus.—At the Royal Society Soiree on the 10th of June, 1896, a special piece of apparatus was shown by Prof. Ayrton and Mr. T. Mather by means of which both the permeability and hysteresis could be determined in a few minutes. The set was intended for the use of students and in accordance with the practice of the Professor each instrument required in the operation is mounted upon a base-board so that the student may lose no time in finding a switch, meter, etc., which he may require.

The apparatus consists of a small separately excited dynamo with a very short air space of large area, so that the magneto-motive-force spent in the air-gap is a small proportion of the whole, whilst the test piece forms the yoke between two massive pole-pieces and is comparatively long. The dynamo is driven by a small motor M, see Fig. 17, and the other end of the armature is connected by means of a short spiral spring to the

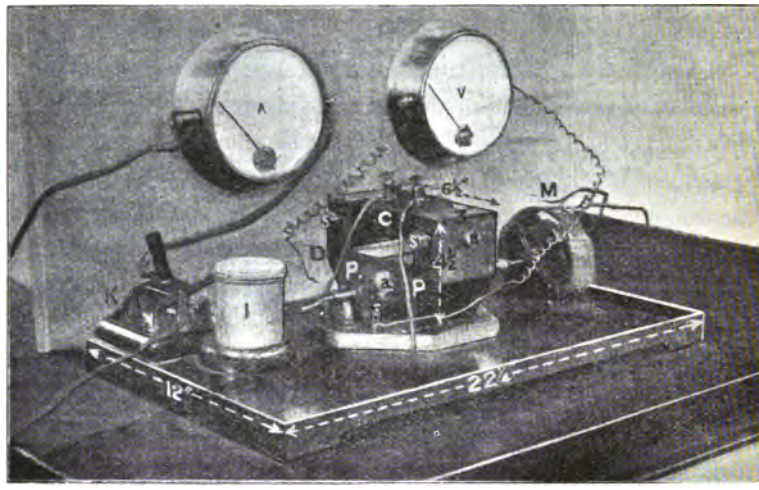
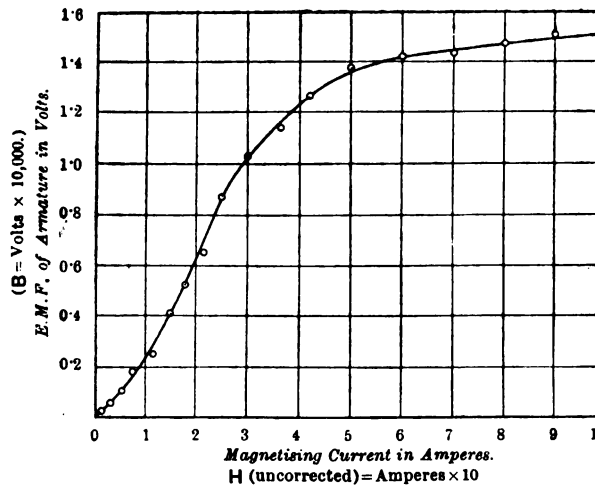


Fig. 17.

speed indicator I. The current which passes round the magnetising coil C passes through the ammeter A, so that the ampere-turns is a constant multiple of the readings of the ammeter. The electro-motive force produced is indicated by the volt-meter V. In the particular machine when run at a speed of 1,280 revolutions per minute the induction of the test piece is equal to 10,000 times the E.M.F. in volts generated in the armature. Thus the volt-meter gives the value of B directly. Similarly the windings of the coil C are so arranged that the magneto-motive force per centimetre of the bar is either one or ten times the current in amperes; thus the ammeter reads directly the magnetising force. In this way the determination of magnetisation curve and the hysterisis loop is reduced to taking a series of simultaneous steady readings of the ammeter and volt-meter taking care to keep the speed of the motor constant.

When more accurate results are required, a comparison may be made with a standard bar or test piece, the properties of

which have been accurately determined by one of the ballistic methods previously alluded to. The compactness of this arrangement will be understood from the dimensions of the base-board, which are 22¼in. long by 12in. broad, occupying a vertical height of under 6in. The illustration is reproduced from the *Electrician* for August 28th, 1896, where a more complete description will be found. In the figure the test piece is the round rod marked B, but it is obvious that the machine may be modified to receive rectangular pieces or bundles of plates without disturbing any other part of the apparatus. Figs. 18 and 19 show two curves that have been obtained by the use of this machine.

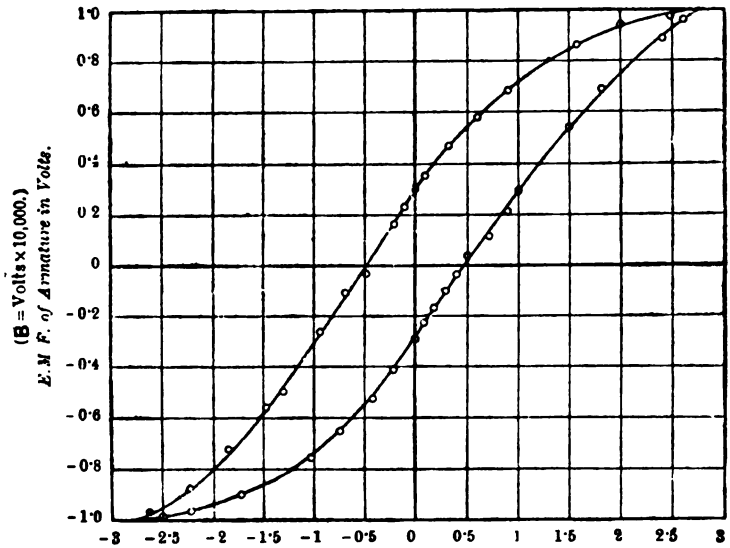


–Permeability Curve of a Specimen of Unannealed Swedish Iron.

Fig. 18.

A similar machine is described in the *American Electrician* of September, 1899, by Mr. C. P. Poole, which he states has been in regular use with very satisfactory results in actual shop work for several years. The following are the particulars:

"The pole-pieces were 5in. square, with the edges rounded off to ½in. radius; the cross-section was maintained unchanged



Maximum B = 10,000 Volts. H (uncorrected) = Amperes × 10.
Hysteresis Loop for Unannealed Swedish Iron.

Fig. 19.

up to the air-gap. The bottom of each pole-piece or yoke was slotted, the slot being 2in. wide and $1\frac{1}{2}$in. deep; a foot-piece was provided for each yoke, having a central rib fitting snugly in the slot and tapering from $\frac{3}{8}$in. high at one end to $\frac{3}{4}$in. at the other, as shown at the left of the sketch, giving the slot in the yoke an inclined floor. The yokes were bolted to a heavy wooden base, the bolts passing through the foot-pieces just described, so as to make their position relative to the yokes permanent.

The test piece was 2in. wide, fitting within the yoke slots snugly; $\frac{27}{64}$in. thick and 15in. long. The distance between the sides of the yokes was 5in., and the exciting coil was $4\frac{15}{16}$in. long over the heads, so as to be easily removable. The test piece was clamped firmly against the surfaces of the yokes forming the upper wall of the slots by means of wedges driven

in at each end, as indicated by dotted lines; these did not need to be driven hard home by any means, a couple of light taps with a machinist's hammer, after being pushed in as far as possible by hand, being sufficient.

The armature core was 6in. in diameter and the radial depth was $1\frac{1}{4}$in.; the net axial length was 4in., giving a cross-section of 10 square inches. Fibre end rings were used to fill out the length of armature necessary to put the clamping rings (of composition metal) beyond the reach of the field, and the armature was wound, ring fashion, with three layers of No. 13 wire, 375 turns per layer, giving a total of 1,125 turns. The length of each air gap was $\frac{1}{4}$in; the core was smooth.

The exciting coil was $4\frac{5}{8}$in. long, net, and wound on a bobbin of very thin brass, the interior of which measured $2\frac{1}{16}$in. by $\frac{15}{32}$in., the clearance being just enough to permit it to slip over the test piece readily. The coil consisted of No. 12 wire wound in two layers of 50 turns each, so that each ampere of exciting current gave 100 ampere-turns. This coil was excited from a storage cell capable of a discharge rate of 30 amperes, less than two volts being required at the highest magnetic densities. The magnetic circuit (beyond the test piece) required 50 ampere turns per 1,000 gausses density in the test piece, so that it was a simple matter to deduct from the total exciting force (in ampere turns) that portion used elsewhere than in the specimen. The speed of the armature was 1,017 revolutions per minute, at which speed a volt-meter connected to the brushes indicated one volt for each 1,000 gausses in the test piece, making the apparatus practically direct-reading. An ordinary Weston voltmeter was used, having a range of 150 volts, but it would have been more convenient, obviously, to use an instrument of lower range with a wider scale.

The armature was driven by a small plating machine used as a motor and supplied from two storage cells, a liquid rheostat

being used in series with the armature for regulation as the E.M.F. of the cells became lower; the speed was carefully taken four or five times for each test with a portable tachometer, and the value ascertained originally to be the proper one was, of course, secured before testing.

The machine was calibrated, so to speak, by using a "standard" piece of wrought iron, the permeability curve of which had been previously determined by several ballistic galvanometer tests, and, although this piece was religiously preserved and the machine frequently tested with it, it was never found to vary from the results originally obtained.

The reason for using a test piece of rectangular cross-section and lapping the ends was that the machine could be used for testing sheet iron, the sheet being cut into strips of the proper length and width, and enough of them bundled together to make the requisite thickness. For testing solid metal only it would have been more desirable to make the test bar round and only 5in. long (or $4\frac{31}{32}$, to slip easily between the yokes). Firm contact at the ends could have been secured by means of a tightly fitting plug, screwed through one yoke so as to butt against the end of the test piece. Then the exciting force could be expressed in ampere-turns per inch of length, whereas with the rectangular test piece the permeability curve had to be plotted first, the abcissae being in ampere-turns instead of in terms of H. It was intended originally to thus build the machine, but the more universal character obtained by making the test piece rectangular outweighed the greater convenience incidental to the other construction."

Fig. 20 gives a general arrangement of this particular variation.

Ewing's Permeability Bridge.—Professor Ewing exhibited at the soiree of the Royal Society, May, 1896, a permeability bridge or an instrument for obtaining the magnetisation curve without

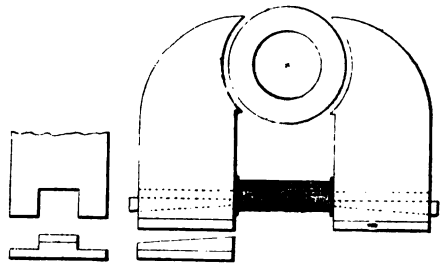


Fig. 20

the use of a ballistic galvanometer. The principle made use of in this instrument is analagous to that involved in the measurement of the resistance by means of a Wheatstone bridge, where it will be remembered that an unknown resistance is balanced against a known resistance, a galvanometer being used to indicate when a balance is obtained. Professor Ewing uses two bars, see Fig. 21 ; a is a standard bar and a^1 the test bar.

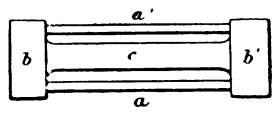
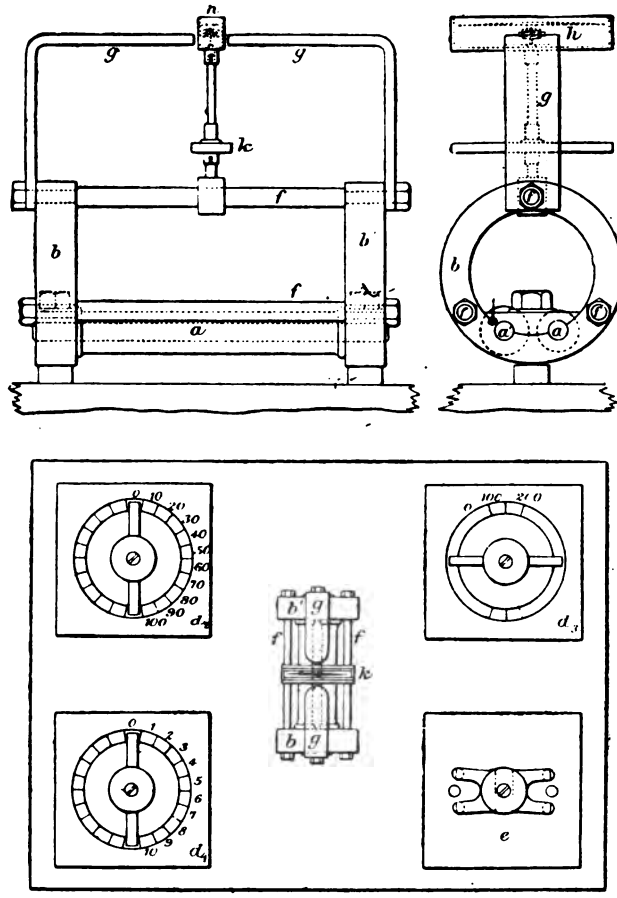


Fig. 21.

Each of these bars is surrounded by a magnetising coil independent of each other. So long as the magnetic induction is the same in each bar there will be no difference of magnetic potential between the yokes b and b^1. So that if these yokes are connected by a third magnetic conductor c, there will be no magnetic induction in c. The absence of magnetic induction in c is tested by making a gap and placing there a compass needle. Fig. 22 shows the side and end elevations of the arrangement of the bridge, which will be easily followed, k is a directing magnet adjustable in position to counteract the effect of any external field upon the detector h. The arrangement of the whole of the apparatus is diagrammatically shown in



PERMEABILITY BRIDGE.

Fig. 22.

Fig. 22, where it will be seen (that resistance coils are provided) that the general arrangement resembles a Wheatstone bridge. The standard bar a has a coil of 100 turns, and as its length is 12·56 centimetres, the corresponding magnetising force h^1 is 10 C G S units per ampere of current. The bar under test a^1 has a coil which can be varied from 1 to 210 turns by means of the dial switches d^1, d^2, d^3. Of these d adds one turn for

each step, d^2 10 turns per step, and d^3 100 turns per step. In each case the act of switching in more turns cuts out equal resistances and *vice versâ* by means of the contacts on the opposite side of each dial, so that the current flow is not changed in varying the number of turns. The current is brought to any desired value by means of external resistances and read on an ammeter. It is then reversed repeatedly by means of the reversing key *e*, whilst the dial switches are manipulated until the reversal does not produce any permanent displacement of the detector needle *h*.

The complete instrument is shown in Fig. 23.

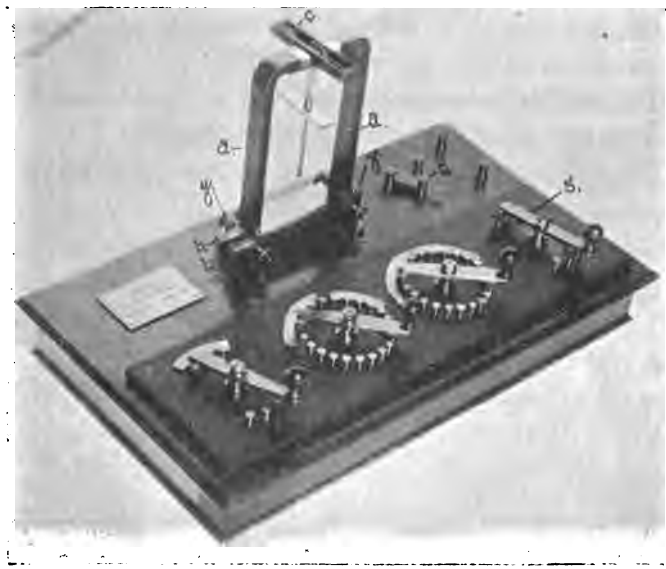


Fig. 23.

In the preceding the specimens tested have formed in each instance either part of the magnetic circuit, or the whole circuit. In the ring methods the path of the magnetic lines lie wholly within the iron, but in the case of the bar methods one or more

joints are unavoidable, and so errors are introduced. These breaks in the continuity of the circuit may be a joint, or the adjacent faces may be separated by air or other non-magnetic body by a greater or less distance. This is usually termed the air gap.

Effect of an Air Gap.—Since the reluctance of air is many times that of the iron, it is evident that to force the lines across an air gap will require a corresponding increase of H. An example will make this clearer. Take a cubic centimetre of air and from Equation (3) we have that

$$H = 1{\cdot}257 \times (\text{Ampere-turns});$$

so that with a magnetising force of 10 Ampere-turns, the intensity of H in C G S lines is $= 1{\cdot}257 \times 10 = 12{\cdot}57$. Referring to Fig. 24, we find that for wrought iron the intensity obtained with 10 Ampere-turns per centimetre is about 11,600 C G S lines, an increase that shows why the electrical engineer is so anxious to use a small air gap in his dynamos.

Effect of Joints.—A joint is only an air gap in which by mechanical means the thickness of the film of air is reduced to vanishing point. Prof. Ewing has investigated this subject very fully, using different magnetising powers, upon a solid bar first and afterwards cutting it into two, four, and eight pieces. The ends of the parts were faced up as true planes, and the results obtained are summarised by Dr. Sylvanus Thomson in the following table;—

H	B.				Mean thickness of equivalent air-space for one cut.		Thickness of Iron of equivalent reluctance per cut.	
	Solid.	Cut in two.	Cut in four.	Cut in eight.	Centim.	Inch.	Centim.	Inch.
7·5	8,500	6,900	4,809	2,600	0·0036	0·0014	4·	1·57
15·	13,400	11,550	8,900	5,550	0·0030	0·0012	2·53	1·00
30·	15,350	14,550	12,940	9,800	0·0020	0·0008	1·10	0·433
50·	16,400	15,950	15,000	13,300	0·0013	0·0005	0·43	0·169
70·	17,100	16,840	16,120	15,200	0·0009	0·0004	0·22	0·087

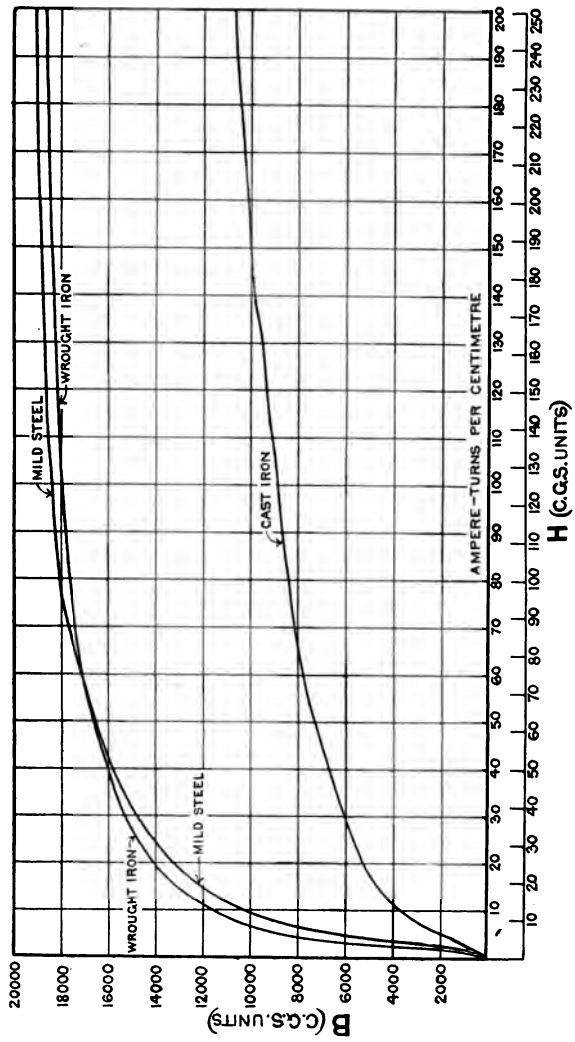


Fig. 24.

From the table it is seen that the loss of B due to the cuts decreases as the values of H increase, which is due to the pressure exerted by the magnetic forces. This pressure may be

found by means of Equation (9), when it will be found that the above values of B correspond to about 140lbs. per square inch.

The joints were next tested under various loads, and the following results were obtained :—

When the iron bar was compressed under a load of 3,210lbs. per square inch, the joint showed a steady reduction of reluctance as the magnetic force was increased.

H.	B (Under a compression of 3,210 lbs per sq in.		Thickness of mean equivalent air space in millimetres.
	Solid Bar.	Cut in Eight.	
7·5	7,500	3,600	0·020
10·	10,000	4,900	0·019
20·	13.900	8,300	0·018
30·	15,200	10,700	0·017
50·	16,500	13,750	0·011
70·	17,200	15,700	0·007

Experiments were also made with a weak magnetic field, and the loads varied, with the following results :—

Load.		B (where H = 5).		Thickness of equivalent air space in millimetres.
Kilos. per sq. centim.	Lbs. per sq. inch.	Solid Bar.	After cutting and facing.	
0·	0	5,600	4,700	0·022
56·5	804	5,400	4,670	0·020
131·0	1,860	4,700	4,200	0·017
169·5	2,400	4,050	3,800	0 010
226·	3,210	3,650	3,650	0·

Effects of Stress.—If a tensile stress is applied to iron under a magnetising force, it is found at first to increase its permeability, whilst a compressive stress decreases it. A piece of annealed iron wire that has been previously stretched behaves like a piece of hard steel. All such operations as rolling, hammering, twisting, &c., impair the magnetic quality, and the

British Post Office include in their specifications the condition that the cores must not be filed after being annealed.

The Effect of Heat is somewhat singular, as with temperatures not exceeding 760° C the permeability of iron in a weak magnetic field is greatly increased, but if the temperature be increased it suddenly falls, and at 780° C it ceases to be magnetic; but in a strong field the increase of temperature at first diminishes the permeability slightly, afterwards it rapidly increases until at 780° C it disappears altogether.

Steel behaves differently as in a weak field the increase of temperature is accompanied by an increase of permeability until at about 700° C it disappears altogether. In a field of about H = 2 its magnetisation is greater, and the final drop sets in below 700° C. In a strong field the permeability falls steadily with the increase of temperature.

Hysteresis.—If the figures 9, 12, 14, 15 and 19 be examined it will be noticed that there is a lag in phase between the effect produced by a magnetising force upon iron and steel. Prof. Ewing has given the name "hysteresis" to this effect. It will be noticed that the curves are closed loops if the iron be put through these variations of magnetising force repeatedly, and the area enclosed represents the work that is expended upon the iron, raising its temperature in the process.

In continuous current dynamos and motors, the iron cores of the armatures are subjected to a cyclical change of this character, and a certain amount of energy is converted into heat by magnetic hysteresis. As the rise of temperature, which a given machine attains in work, is one of the factors limiting its output, it is necessary, in designing an armature, that the amount of energy wasted from this cause should be capable of estimation. Ewing gives a curve connecting the energy dissipated in ergs per cubic centimetre per cycle with the maximum induction density B for complete cycles of magnetisa-

tion for soft wrought iron. This curve is reproduced in Fig. 25. For any given maximum induction density the dissipation in joules per cubic centimetre per cycle is obtained by dividing the

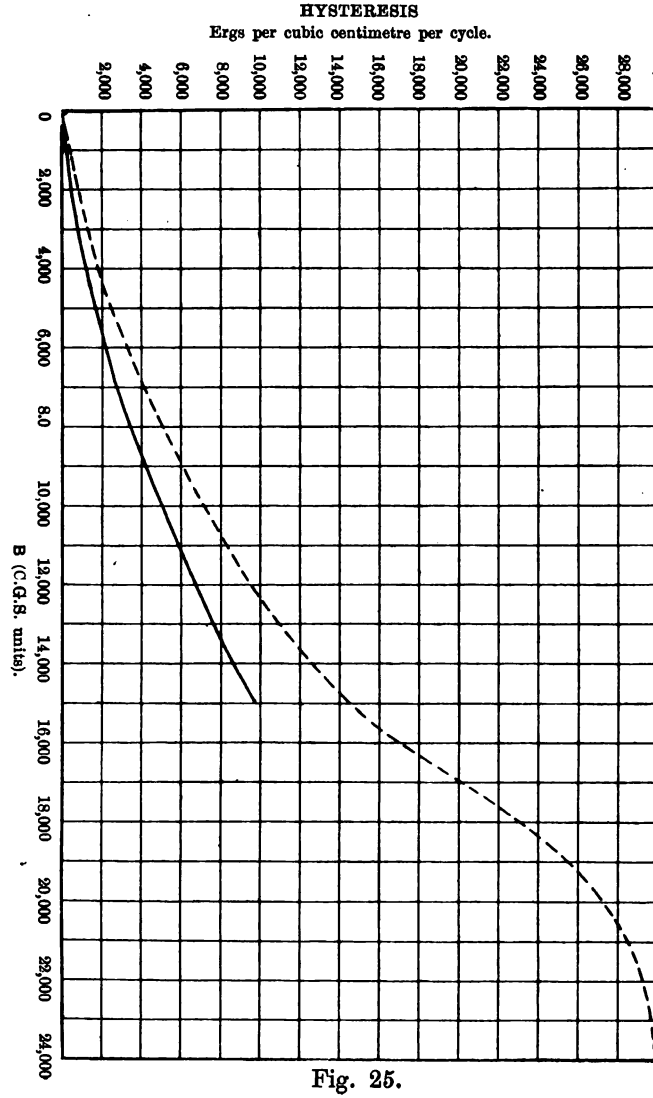


Fig. 25.

reading in ergs from the table corresponding to the maximum induction density by 10^7 (10^7 ergs = 1 joule), and this value multiplied by the volume in cubic centimetres of the iron gives the hysteresis in joules per cycle. This product multiplied by the number of complete cycles per second, gives the work done per second, or the heat produced in the iron in joules per second. Now, 1 joule equals 1 watt per second, and if

x = joules dissipated per cubic centimetre per cycle $= \frac{\text{ergs}}{10^7}$;

v = the volume of iron in cubic centimetres;

f = the number of complete cycles per second,

the hysteresis loss is equal to $x\,v\,f$ watts.

EWINGS' HYSTERISES TESTER.

The hysterises tester was described in a paper read before the Institution of Electrical Engineers, 25th April, 1895, from which the following account is extracted:—

The basis of the instrument is the mechanical measurement of the work done in causing reversals of magnetism to take place in the iron under examination. The iron to be tested is cut or stamped in the form of strips, which are 3in. long and $\frac{5}{8}$in. wide, and filed accurately to length in a hardened steel clamp. The number of these pieces taken to form a sample depends on the thickness of the sheet, and usually does not exceed seven.

The bundle of pieces forming the sample is placed in a carrier *a*, Fig. 26, and is covered with a vulcanite washer and secured by two clamps, *b*, *b*. The carrier is made to rotate by means of the friction pulley *c* and driving wheel *d*. This causes the sample to revolve between the poles of the permanent magnet *e*, with the effect that its magnetism is periodically reversed. The work done in reversing the magnetism in consequence of hysteresis causes a mechanical moment to be exerted by the revolving sample upon the magnet; and the magnet,

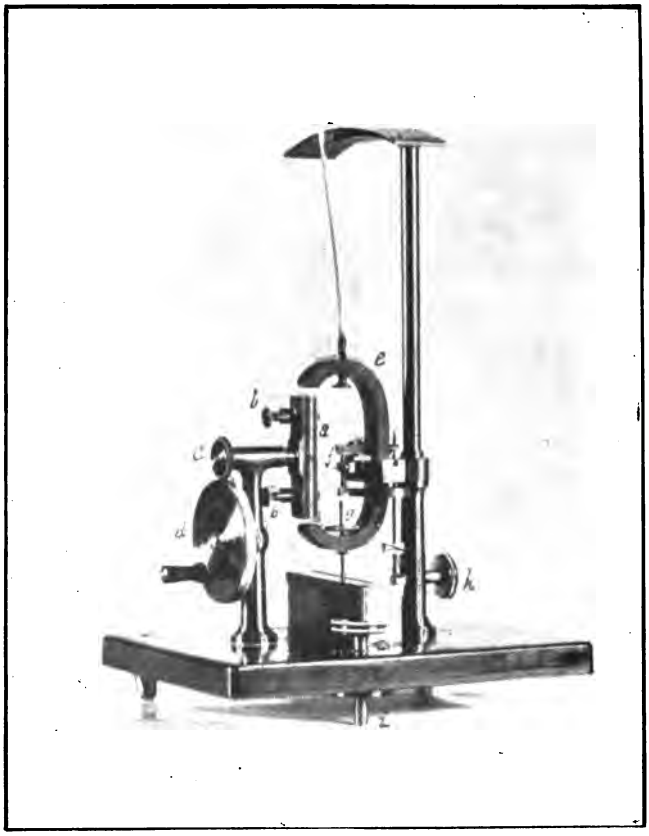


Fig. 26.

being supported upon a knife edge at *f* in line with the axis of the carrier, tends to follow the sample, and is deflected through an angle which serves to measure the work expended. Since a definite amount of work is done per reversal, whatever the frequency (so long as that is not so high as to make a sensible addition to the work by inducing currents), the deflection of the magnet is independent of the speed at which the carrier revolves, and no special care has to be taken to turn the handle

at a uniform rate. If the rate is very slow, the magnet will show each individual impulse which it receives as the ends of the sample pass its poles, but when the speed is sufficiently raised these impulses blend into a steady deflection, and the speed may be further augmented to the extent of doubling it, or more, without making the deflection change. The deflection is observed by means of a pointer and scale above the magnet, and the swinging of the magnet is checked by a dash-pot below, consisting of a vane or spade moving in a box filled with oil. The stability is adjusted to give any required degree of sensitiveness, by means of the weight *g*, which travels as a nut upon a screw fixed to the magnet, and serves to raise or lower the centre of gravity of the oscillating system. The magnet swings about a knife edge working in an agate trough, and a lifting

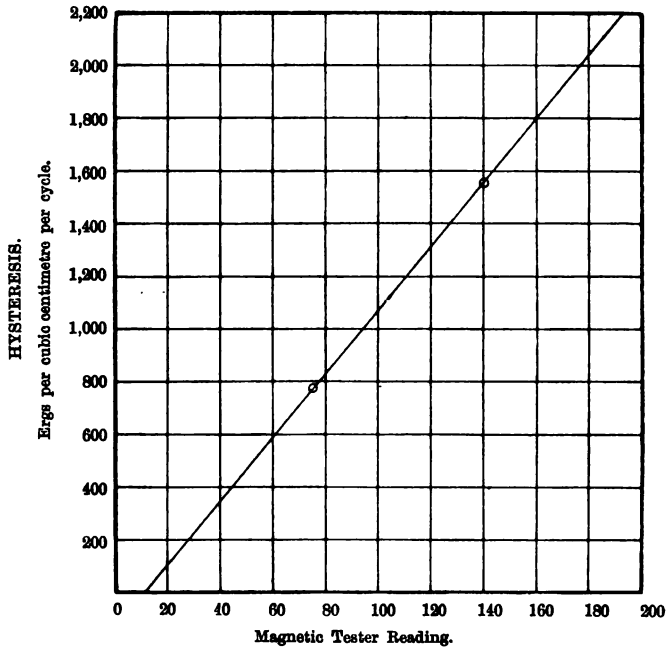


Fig. 27.

arrangement like that of a balance is provided, operated by the handle *h*, to save the knife edge from unnecessary wear or injury. The pointer is set to zero in the middle of the scale by means of a nut which runs on a screw projecting sideways from the middle of the magnet, and a more delicate adjustment of the zero may be effected by means of the levelling screw *i*.

Two standard samples of iron are provided with each instrument, along with a table stating their hysteresis, as found by reference to ballistic experiments, in ergs per cubic centimetre per cycle, and also in watts per pound at an assigned frequency.

To determine the hysteresis, the necessary strips of iron are cut and filed accurately to length in the gauge. The instrument is then levelled, and the pointer adjusted to zero of the scale. One of the standard samples is then inserted in the carrier *a*, care being taken to keep the ends of all the strips flush, and to push the bundle up against a stop at one end of the carrier. The magnet is now lowered on to its knife edge. and the handle turned just quick enough to give a steady deflection, and the scale reading observed. The direction of rotation of the handle is now reversed, and the steady scale reading taken on the opposite side of the zero. (This eliminates any inaccuracy in the initial adjustment of the zero.) The sum of the two readings is then taken as the total deflection. The deflections given by the second sample are then determined in the same manner, thus standardising the instrument as the hysteresis of of the standard samples has been determined ballistically.

Each bundle of prepared sample strips is then inserted in turn in the carrier, and the scale readings taken for right and left handed rotation of the handle, just as for the standard samples.

To determine the hysteresis in ergs per cubic centimetre per cycle, the scale readings of the tester for the two standard samples are plotted on squared paper in relation to their known hysteresis, and a straight line drawn passing through these

points. Thus, suppose the hysteresis of the two standard samples is stated as 780 and 1,560 ergs per cubic centimetre per cycle, and that the tester reading for the first sample is 76 scale divisions, and for the second sample 140 scale divisions. These values are plotted as in Fig. 27, in relation to their known hysteresis, and a straight line drawn passing through these two points. The hysteresis of the prepared samples can then be read off in ergs per cubic centimetre per cycle by observing where the scale reading for each sample cuts this inclined line. Say the tester reading, for a sample, is 100 scale divisions; then, by inspection of Fig. 27, the hysteresis corresponding to this scale reading is 1,070 ergs per cubic centimetre per cycle.

The induction density B attained in the specimens is about 4,000 lines, and for higher or lower induction densities the hysteresis in ergs has to be multiplied by a factor to determine the loss at the given induction density. The following table of factors is given in the paper :—

Induction density B.	Relative amount of hysteresis.
2,000 lines	0·33
2,500 ,,	0·47
3,000 ,,	0·63
4,000 ,,	1·00
5,000 ,,	1·41
6,000 ,,	1·89
7,000 ,,	2·41
8,000 ,,	3·00

These values for B well cover the ground for the induction densities employed in alternating-current transformers, but B in continuous current armatures is usually much higher, and the following table is therefore added to give the approximate factors by which the hysteresis, as determined by the tester, should be multiplied to obtain the hysteresis per cubic centimetre per cycle, and hence to determine the rate of doing work from hysteresis in watts.

Induction density B.	Relative amount of hysteresis.
10,000 lines	3·9
12,000 ,,	5·0
14.000 ,,	6·6
16,000 ,,	8·5
18,000 ,,	12·0
20,000 ,,	13·0

The magnetic quality of the iron employed has progressively improved in recent years; nevertheless bad batches do come to hand occasionally, and although the tester, as usually made, cannot give directly the hysteresis at the high values of B usual in continuous-current armatures, still it enables very satisfactory tests to be made quickly and simply of the quality of the iron used. Sheet iron or mild steel which shows a greater hysteresis than about 1,200 ergs per cubic centimetre per cycle for B = 4,000 should be rejected.

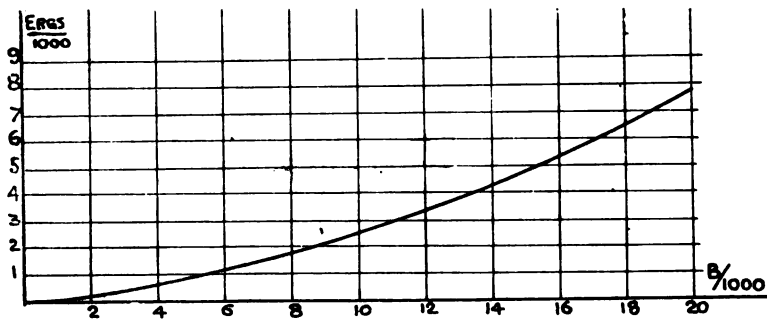


Fig. 28.

The curve shown in Fig. 28 gives the hysteresis loss in ergs per cycle, per cubic centimetre, for the ordinary range of densities found in practice, calculated by the formula:—

$$h = 126 \left(\frac{B}{1{,}000}\right)^{1\cdot6}$$

In conclusion, I have to thank the proprietors of the *Practical Engineer* for permission to make use of several illustrations and descriptions of apparatus embodied in this paper, and the larger

part of magnetic data, &c., has been drawn from the papers and researches of Professor Ewing and Dr. Hopkinson, who are the standard authorities upon this subject.

In the Appendix I have added the method adopted by Messrs. Evershed and Vignoles for calibrating their ballistic galvanometer, which they used in their researches, and I may perhaps draw special attention to the few remarks at the end in which they describe the steps taken to avoid errors in their work.

APPENDIX.

The following convenient method of standardising a ballistic galvanometer will, the author thinks, be found useful, especially the concluding remarks upon the elimination of errors. It is taken from the paper by Mr. Vignoles, which was published in the *Electrician*, May 15th and 22nd, 1891:—

"The ballistic galvanometer, of which details are given in the table, appears to the naked eye a rough piece of apparatus, but it has performed its work admirably, and has never given us any trouble.

TABLE.—BALLISTIC GALVANOMETER.

Length of needle = 4·8 cm. Sect. area = ·0726 sq. cm.
Period = 3·8 seconds.
Resistance = 69·6 B A ohms at 20°.
Max. angle of deflection = 9°.

My audience must remember that all these experiments were carried out in engineering works, and not in a laboratory; and this fact made us anxious to eliminate every source of error. We had to devise a ready method of standardising the galvanometer every time we used it, as motors and dynamos in the immediate neighbourhood are not conducive to constancy in the earth's field.

We therefore made a solenoid of length 120 cm. and diameter 8 c.m. Its length being great compared with its diameter, the field at its centre could be accurately calculated, from the well-known formula

$$H = \frac{\cdot 4\ \pi\ C\ N}{l}$$

where C is current in amperes, N the number of turns, and l the length.

Assuming that the permeability of the broomstick on which the solenoid was wound to be the same as that of air

$$H = B$$

we thus get the number of Thoms* per unit of area at the centre of the coil.

The secondary, wound inside the solenoid in a groove in the broomstick, had 1,000 turns of very fine wire. Its average area was 5·0 sq. cm.

$$H \times \text{area} = \frac{\cdot 4\ \pi\ C\ N}{l}.a$$

gives the induction cutting the secondary.

This broomstick standard thus gives us a means of calibrating our galvanometer as well as standardising it.

The theory of the ballistic galvanometer given in text books says, that the induction is proportional to the throw, under certain conditions, one of which is that if there is damping, corrections must be made by means of a "logarithmic decrement." We did not quite know what a logarithmic decrement was, and so we preferred to try whether our scale was a straight line, by going to the *fons et origo* of all knowledge,—experiment.

$$\theta \propto \frac{1}{R}$$

if B × area is kept constant; where θ is the throw, R the resistance of the circuit, and B the induction density. Then we took a curve of B and θ for constant resistance and turns, and this curve cannot be distinguished from a straight line.

* This name is used by Messrs. Evershed & Vignoles to denote a magnetic line of force.

If, therefore, all deflections are taken with the same resistance in circuit, the formula is

$$\theta = \frac{a\,n}{\mathrm{R}}\,(\mathrm{B} \times \text{area})$$

where a is a constant depending on the galvanometer.

Owing to the variation of the amount of damping with the resistance of the secondary circuit, this formula is not true (except at the resistance at which the galvanometer was standardised), unless the damping be properly allowed for.

Deflections taken at various resistances can be made comparable with one another, by substituting for them uniformly the value they would have had if some fixed resistance (infinity for convenience) had been in circuit.

A curve of coefficients, by which throws at various resistances must be multiplied in order to reduce them to "throw on open circuit" is easily obtained.

A fixed impulse is given by means of an external coil by tapping a key, and the deflection noted for open circuit, and for various resistances. The damping increases as the resistance of the circuit decreases, and the percentage difference from the throw at infinite resistance is thus obtained. By means of it all throws can be reduced to throw an open circuit by multiplying by the required percentage. The curve is a rectangular hyperbola.

We are now prepared to standardise the galvanometer.

Since $$\theta = \frac{a\,n}{\mathrm{R}}\,(\mathrm{B} \times \text{area}),$$

the induction $= \mathrm{B} \times \text{area} = \dfrac{\mathrm{R}\,\theta}{a\,n}$;

whence we see the $\dfrac{1}{a}$ or g, the galvanometer constant is to be obtained. Now,

$$g = \frac{1}{a} = \frac{\mathrm{R}\,\theta}{n\,\mathrm{B}} \times \text{area},$$

and thus one deflection from a known B in the broomstick gives the required constant.

Any mutual induction coil may be standardised by means of the solenoid, and used as a standard in place of the somewhat clumsy broomstick.

In our "Mutual Inductioner," 1,278 Thoms cut the secondary for 10 amperes in the primary. Everything was now ready, except that all-important item in a research, the elimination of "niggers." I may mention some of these, in case any of you ever have to investigate force-induction curves.

It is necessary to break the primary *very* sharply. We had much trouble from double-breaks until we made a "jumper," in which a copper wire filed to a point was pulled from a mercury cup by elastic. This arrangement is perfectly satisfactory.

Bad contacts in the secondary circuit are a fruitful source of error when working with low resistances. We have made a rocking mercury-cup switch, which when put over to the left, throws the ballistic galvanometer into circuit, and when over to the right short circuits the galvanometer, and puts the remainder of the circuit on to the bridge, so that its resistance can be taken if necessary before or after each deflection, since the resistance alters by heating. To avoid these errors, wind many turns of secondary, so as to have *large* resistances in circuit; in this case the heating of a secondary of a few ohms does not matter.

A great many errors may be due to the currents in the primary circuit affecting the ballistic galvanometer directly. We leave our leads long, and can then raise, lower, or coil them up, till currents in them do not affect the galvanometer. This point is most important, especially with large primary currents. These "niggers" having been discovered and eliminated, we were in a position to begin our research."

DISCUSSION.

Mr. Henry Webb said the paper, as printed in their transactions, would form a practical textbook for the members for a good number of years. They would remember he had brought the matter forward as a topical question at a meeting in the previous session. For many years he had made soft iron cores for the earlier types of dynamos, and he used to be told by the electricians that one core was bad and the other good, and so on, but they never were able to give this information till the machine was finished. Although he made them out of the same metal in the same way and at the same temperature, the results were different, and they could not tell him how to avoid it. When steel came to be used, and steel castings had to serve the same purpose as iron cores, another difficulty arose.

He asked for information as to what chemical analysis would be required in the castings. He was told by one electrician that they wanted plenty of soft iron, and as few other ingredients as possible, and no manganese. He made castings as near as possible to this requirement with no manganese, but still they did not come out perfect. On the other hand he had taken a handful of turnings from some castings that had, he was told, proved very satisfactory, and that came from Krupp, of Essen, and found six per cent of manganese in them! The uncertainty that existed on this matter had prevented him putting up steel furnaces for making cores for dynamo machines. He had never been able to get a satisfactory answer as to how the suitability of the iron and steel could be tested before they were actually at work in the finished machine. He had however, that night, obtained some idea of the manner in which tests

could be made, and he thought that if he had had some such information on the point some years ago, he might have been induced to spend some money on steel melting furnaces, and keep up the trade in castings for dynamo machines.

Mr. Chas. Day observed that the methods which had been explained were methods which had been developed by various leading electricians, and although some of them did not pretend to absolute accuracy, they were all what they were represented to be. He was more particularly acquainted with two of the methods described. His firm used the one shown in Fig. 13 to a large extent, they also used the Ewing's tester when a number of tests were to be made, with a view to seeing whether the quality of a consignment of plates was uniform, but they did not greatly need special apparatus of that kind, because they had in the place a great deal of electrical testing apparatus, so that there was not much difficulty about the matter. They could therefore use the more general method of the ballistic galvanometer with greater advantage than would perhaps be possible in a works where they only did a little electrical work, or made steel or iron for dynamo builders. To dynamo builders the curves of hysteresis and permeability obtained by these tests were just as necessary as a knowledge of the stress that could be safely put on any part of his material was to an engine maker. The author had answered in a very complete manner the question he had undertaken to deal with.

Mr. J. Slater Lewis. F.R.S.E., said Professor Ewing's instruments appeared to be the only practicable ones at the present time. They had tried at their works ballistic galvanometers and other apparatus, but these had proved entirely useless in consequence of the disturbance created by the passing of the trains on either side of the works. The very delicate

ballistic galvanometer could not be kept still, at any rate at their place, and the idea of testing steel with that had to be abandoned. They had found it more satisfactory to send the material to London, where there were adequate arrangements for carrying on tests in a complete and delicate manner. Prof. Ewing's permeability and hysteresis instruments, however, appeared to supply a long-felt want. There were no galvanometers to be disturbed. The only disturbing element in the apparatus seemed to be the magnetometer, and that was not particularly delicate, because it was controlled to some extent by the magnet underneath the needle.

If they had to prepare bars of iron, as in Dr. Hopkinson's and Professor Thompson's methods, of a definite length and diameter, and fit them up almost as a man would put the parts of a watch together, it became an expensive and troublesome piece of work; there was also the question of air-gaps and joints to be considered, to the effect of which the author had referred.

There was none of this trouble with Prof. Ewing's instrument, which was capable of being used in any ordinary works, notwithstanding the use of steam hammers, the passing of railway trains, &c. It was a practicable instrument that could be used by steel makers, dynamo makers and manufacturers.

The hysteresis test could be quickly carried out; they had simply to get the piece of steel, or iron, or thin plates of iron, cut or machined to the proper size, put into the clamp and revolve in the magnetic field of the apparatus, and make the calculation from the reading on the scale above.

As to steel castings, as they all knew, they were very troublesome things to make. Only the previous day they had been making still further experiments with a view to improving the quality of the steel and to get increased permeability, and they hoped they would arrive at very satisfactory results.

If they had instruments like Professor Ewing's—and they would probably be getting them—they would be able to complete their tests within a very short time, whereas when they sent their charcoal-iron plates, or pieces of steel to London they were often kept there two or three weeks, and by the time they came back they had perhaps forgotten all about them.

The reason why steel castings were used by dynamo manufacturers was principally because a type of dynamo—multipolar—was now coming into use, in which plain forgings were impossible. They must have a casting, with corners, projections, ends, &c., and it must come straight from the foundry and need little machining. They (Messrs. P. R. Jackson & Co.) had at present in hand a magnet, 14 feet diameter, and weighing 18 tons, which had feet, poles and other features. It would be impossible to forge that. That was why they used steel castings instead of forgings. In making a casting of that kind, if they did not take the greatest care, they would have one part hard and of poor quality, and the other part of good quality, which would create trouble when they came to run the machine. Steel castings for dynamos should be very low in carbon and have as little manganese as possible; in their castings it was not ½ per cent. They required as much pure iron as it was possible to get the castings to stick together. A steel founder who wished to make successful steel castings for dynamos should have sufficient moulds to permit special blows for dynamo castings only. This of course presented a difficulty unless they had a steady trade for such castings and a steady trade for other castings where permeability was of no consequence.

The paper had dealt with a subject which had required efficient treating for some time past, and Mr. Wells had handled it in a very full and scientific manner, which reflected great credit upon him.

Mr. F. Reid asked which of the various instruments described Mr. Wells would recommend for ordinary workshop use. As to air gap, he thought that in the Ewing permeability bridge where the small bars fitted in the holes, they would get air-gap if these were not of exactly the same diameter all through.

Mr. Wells in his reply observed that he had advanced nothing but what was perfectly orthodox, as he believed in being careful before bringing forward anything new. In making progress of any sort it was only safe to do so slowly. He could fully corrobate Mr. Day's experience as to the curves and their value. They could get within a very small percentage, and he would almost undertake to say that a dynamo builder would come nearer the result he intended to secure than a steam engine maker could do. He had frequently been able to set right dynamos which would not work properly by means of these curve tests.

In doing these things, however, they must make the tests carefully, and the plotting must be accurately done. They could then obtain very close results indeed, either for alternators or direct current machines.

As to the question of air gap, they must remember that Prof. Ewing's method was a comparative method, and the error on one side was practically the same as on the other. As a practical matter, they could take it that the machine was reliable, but theoretically the difficulty was there. It was got over, however, by the comparative nature of the test and the fact that the bars were comparatively large and they got a great deal of surface. With respect to the quality of iron and steel, he believed it was desirable to have it as pure as possible, without its breaking to pieces.

Mr. T. Ashbury, in proposing a vote of thanks to the author, observed that they were greatly indebted to Mr. Well's for the

able and clear manner in which he had treated the subject, and his paper would prove of great value for reference when printed in the "Transactions" of the Society.

Mr. Day seconded the motion which was unanimously adopted, and Mr. Wells having acknowledged the vote, the proceedings closed.

THE RELATIVE EFFICIENCIES OF TRIPLE AND QUADRUPLE EXPANSION ENGINES.

READ SATURDAY, 24TH NOVEMBER, 1900,

BY

A. L. MELLANBY, M.Sc.,

(MANCHESTER.)

The present paper is submitted to the Association with the intention of, firstly, giving figures from actual trials, by means of which the water consumption and horse-power of triple and quadruple expansion engines working under similar conditions may be compared; and, secondly, of trying to indicate the reasons which determine why one type of engine should be more economical than another.

To anyone who has studied the steam engine, it is obvious that a large amount of experimental research is necessary before any definite theory can be formulated, and although, at the present time, there are many experimental engines in the various colleges throughout the kingdom, it is remarkable that they have done so little to help us to a real knowledge of the actual processes involved when a steam engine is at work. For the most part the uses of the ordinary college engine seem to be simply to teach students how to manipulate the indicator, and to make the various necessary measurements of coal, feed, circulating water, &c. That an experimental engine might be used for some other purpose, such as to find out where the actual losses in engines take place, and the reasons for those losses, and to be thus a means of helping engine builders to

make a better article seems seldom to occur to those responsible for their running.

The chief reason for the, so far, comparative uselessness of experimental engines appears to lie in the fact, that in very few cases has an attempt been made to attack the steam engine problem in a really scientific manner. An engine is thought to be such a *practical* thing that a *scientific* investigation of its working has always appeared unnecessary. Yet, if we consider the amount of mathematical and physical skill that is expended upon what we might call the relatively simple researches carried out in physical laboratories, it appears that the complicated operations taking place in the cylinder of an engine during the admission, expansion, exhaust, and compression of the steam, are deserving of the closest and most skilful investigation.

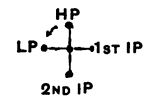
The experiments to be described were made upon the engines at the Durham College of Science, Newcastle-on-Tyne. They are, at present, the finest experimental engines in this country, and were designed chiefly to afford information to marine engineers as to the most economical methods of working multiple expansion engines. So far, they have afforded results of the greatest importance, and have had a considerable effect upon the design and proportions of marine engines, at least upon the North-east coast. Full particulars of them can be obtained from a paper read by Professor R. L. Weighton, M.A.* when the interesting fact will be noticed that the engines were presented to the college by the various firms situate on the North-east coast, each firm making some particular part, and one firm undertaking their erection.

It is not claimed that the trials about to be given are to be considered as model trials, but rather to show how much they leave to be discovered, and also that special methods

* Proceedings of the North-East Coast Institution of Engineers and Shipbuilders. Vol. XIII.

are required in order to specify the reasons for the losses incurred, before we can hope to obtain any definite theory of the steam engine.

The sizes of cylinders used in the trials were as follows:—For the quadruples, HP 7in., 1st IP 10½in., 2nd IP 15½in., LP 23in. Two sets of trials were made, one with the cranks arranged thus

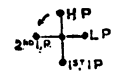


and the other with the cranks arranged thus

For the triple expansion trials two sets of cylinder ratios were used, in one case HP. 7in., IP 10½in., LP 23in.; and the other HP 7in., IP 15½in., LP 23in. The stroke of each cylinder was 18in. The results obtained with the highest boiler pressure (210lbs. gauge) are, of course, the most important; but to avoid comparing isolated results, a complete set of trials was made with each arrangement of cylinders and cranks, at different boiler pressures; the conditions of cut-off, revolutions, and vacuum remaining the same. This allows a curve of results to be constructed, and so enables us to determine and correct any experimental errors that may be made.

The feed water used by the engine was measured by allowing the hot well discharge to flow into graduated measuring tanks. The power of the engine was absorbed by a hydraulic dynamometer of the type introduced by the late Dr. Froude. A specially designed apparatus attached to the brake automatically recorded the brake horse-power. The resistance of the brake could be altered by sluices, and so the revolutions were kept constant as the power of the engine was decreased.

In addition to the experiments recorded here, a large number of preliminary ones were also carried out. The first set of trials was made to discover the best number of expansions for the engines working as quadruples with a boiler pressure at 210lbs. The point of maximum economy seemed to be almost reached when the cut-off in the HP cylinder was at $\frac{2}{3}$ rds. of the stroke, the steam then expanding about 17·4 times. The curve of results showed that a slightly higher efficiency might be obtained with less expansions, but the gain appeared to be so very small that it was not considered advisable to press the boiler in order to obtain the extra steam necessary for a later cut-off. A long series of trials was also made to discover the best points of cut-off in the cylinders other than the HP, and the results of these trials determined the setting of the expansion valves in the experiments described in this paper. Of the two sets of quadruple expansion trials before mentioned, the one with crank angles thus

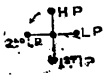


proved the more economical,* and of the two sets of triple expansion trials, that with cylinders, HP 7in., IP 10½in., LP 28in. was the better. These two series of trials only are given here.

The first experiment in each set of trials was made with the boiler pressure at 210lbs, the cut-off in the HP cylinder at 12in. of the stroke, the vacuum at 24in., and the revolutions at 140 per minute. Other experiments were then made at different boiler pressures, down to 90lbs., but the points of cut-off in the cylinders, the vacuum, and the revolutions per minute remained the same, as nearly as possible, in all cases. The principal results of the trials are given in Tables I. and II.:—

* Proceedings of the North-East Coast Institution of Engineers and Shipbuilders. Vol. XIV

TABLES I. AND II.

QUADRUPLE EXPANSION TRIALS. Cylinders, $\frac{7-10\frac{1}{2}-15\frac{1}{2}-23}{18}$ Cranks thus 

Boiler Pressure Gauge.	HP Steam Chest Pressure Gauge.	Hot-well Temperature.	Vacuum.	Barome'r	Revolutions per minute.	Total water used per hour.	IHP.	BHP.	BHP./IHP.	Mean Pressure reduced to LP Cylinder.	Pounds of water used per hour per IHP.	Pounds of water used per hour per BHP.	Heat units used per minute per IHP.	Heat units used per minute per BHP.	IHP at 140 revolutions.	BHP at 140 Revolutions.	Water used per hour at 210lbs pressure, 26in. vacuum and 140 revs.
Pounds.	Pounds.	Deg. Fah.	Inches.	Inches.													
209	200	142·6	24·17	29·77	138·2	1969	157	140	·89	30·3	12·54	14·06	227	255	159	142	1955
190	185	141·6	24·49	30·1	142·5	1891	145	132	·91	27·1	13·04	14·33	237	261	142	129	1819
170	163	138·7	24·32	29·42	143·1	1709	129	116	·90	24·0	13·25	14·72	240	267	126	113	1638
150	147	140·1	24·52	30·1	143·7	1573	118	103	·87	21·9	13·33	15·27	241	276	115	100	1496
130	126	135·7	24·47	29·96	140·1	1334	98	85	·87	18·7	13·61	15·69	245	283	98	85	1302
90	87	130·3	24·53	29·82	145·7	1049	70	56	·80	12·8	14·98	18·73	271	337	67	54	983
TRIPLE EXPANSION TRIALS. Cylinders, $\frac{7-10\frac{1}{2}-23}{18}$ Cranks thus																	
210	202	139·4	23·98	29·45	141·5	2012	150	137	·91	28·3	13·41	14·68	244	267	149	136	1958
190	182	137·8	24·09	29·45	141·2	1840	136	123	·91	25·6	13·52	14·95	247	272	135	122	1792
170	162	135·6	24·27	29·45	139·6	1646	120	109	·90	22·9	13·71	15·10	249	276	120	109	1621
150	143	137·0	23·99	29·45	137·97	1470	101	93	·92	19·6	14·55	15·80	263	286	103	95	1459
130	125	136·5	24·17	29·4	140·63	1354	91	83	·91	17·3	14·87	16·31	268	295	91	82	1315
110	107	132·3	24·07	29·4	141·83	1169	77	69	·90	14·5	15·18	16·94	275	304	76	68	1127
90	89	125·7	24·08	29·4	138·0	1052	61	54	·88	11·9	17·24	19·48	310	352	62	55	1045

Plate 1 has been drawn to show the most important of these results graphically. Brake horse-power has been taken as the base line, and ordinates represent total water used per hour, water per BHP, and per IHP per hour. It will be noticed that in both cases the water used per hour follows the straight line law, and that for a given BHP the quadruple set always uses less water per hour than the triple set.

In order to allow a fair comparison to be made between the trials at different boiler pressures, the total heat units used per hour have been calculated, and are represented in the curve called Total Water per hour, in Plate 1. As the numbers thus found are very large, they have all been divided by one constant factor IIII, and have been called the lbs. of water the engine would use with a pressure of 210lbs. in the steam chest, and a vacuum of 26in. The figures from which the diagram has been constructed will be found in the last three columns of Tables 1 and 2. The actual pounds of water used will also be found in the same tables.

In Plate 2 is shown the relation between water used per horse power hour, and pressure in the HP steam chest. The curves have been produced to show the probable consumption at 250lbs. pressure. It should be noted that these curves do not show the most economical results at the various pressures. Probably the number of expansions at which the engines were working would be the best for about 225lbs. pressure. For all other pressures there would be some other best number of expansions, and consequently, the curve would be altered if it were drawn to represent the lowest consumption of the engines at the various pressures. There seems to be no reason, however, for thinking that the comparative results of the triple and quadruple engines would have been affected. This curve is interesting, because it gives an approximate idea of what the increased

economy is likely to be by the adoption of higher boiler pressures.

Plate 3 has been drawn to show the horse-power generated by the two types of engines at different pressures. It will be seen that for the whole range the greatest power is given out by the quadruple set, but that the difference between the brake horse power, in the two cases, is less than the difference between their indicated horse-power. This is also borne out by the fact that the mechanical efficiency of the triples is higher than that of the quadruples. The small decrease in the efficiency of the former during the range of the trials is well worthy of notice.

In Plates 4, 5, and 6, are given the expanded indicator diagrams of the triple and quadruple engines at their highest pressures. The cards from the triple with 15½in. intermediate cylinder have been drawn to show the effect of the different cylinder ratios upon the shape of the diagrams. The full curve shown is the adiabatic curve calculated from the feed water used per stroke; the area included between this curve, the unbroken vertical line, and the horizontal lines from any two pressures, therefore, represents the total work that could be obtained from the steam working between these pressures.

It will be noticed that in all the trials given, the quadruple expansion engine uses less water per horse-power than the triple expansion engine. In order to fully understand why one engine should be more economical than another, it is not sufficient to examine simply the water used per horse-power per hour. We must take each factor, *i.e.* water and horse-power, separately, and discuss, first, why there should be any difference in the water or steam consumption per hour; and second, why the horse-power developed in each case should differ. It is important to ask ourselves the question—can the consumption per stroke of an engine be affected, when the point of cut-off in its high-pressure cylinder remains fixed, and alterations are

made in the cylinders following? By making the usual calculations it would appear that the same volume of steam must pass into the cylinder at every stroke, and thus the consumption remain unchanged, whatever alterations were made in the other cylinders.

The results from a number of trials are given below; they show that by altering the point of cut-off or the volume, of the second cylinder, the cut-off and admission pressure in the HP cylinder remaining fixed, considerable changes are made in the amount of steam used per stroke. The first table gives the results of experiments made by the writer upon the engines at Mc.Gill University, Montreal. The diameters of the cylinders of this engine are HP 6½in., 1st IP 9in., 2nd IP 13in., LP 18in., and it can be run as a compound, triple, or quadruple.

Dia. of HP Cylinder.	Dia. of 2nd Cylinder.	Pressure in 1st Receiver. Gauge.	Water per hour at 90 revs.
6½in.	9in.	70·6	786
6½in.	13in.	60·2	809
6½in.	18in.	15·0	990

The second table is taken from a series of experiments made upon the engines at Newcastle, to discover the best points of cut-off in cylinders other than the HP.

Dia. of HP Cylinder.	Dia. of 2nd Cylinder.	Cut off in 2nd Cylinder. Ins. of Stroke.	Pressure in 1st Receiver Gauge.	Water per hour at 140 revs.
7in.	10½in.	9in.	88·4	1943
,,	,,	10½in.	79·5	1995
,,	,,	12in.	71·0	2009
,,	,,	13½in.	64·9	2033
,,	15½in.	4½in.	74·7	2045
,,	,,	6in.	57·8	2050
,,	,,	7½in.	45·7	2104
,,	,,	9in.	36·0	2134
,,	,,	10½in.	30·3	2175
,,	,,	12in.	26·7	2197

It can, therefore, be seen that in the Mc.Gill trials the consumption was increased from 786 to 990lbs. per hour, and in

the Newcastle trials from 1,943 to 2,197 lbs. per hour, by, in each case, simply lowering the back pressure of the HP cylinder. There seems, therefore, to be no doubt that the consumption of an engine will be increased if we lower the exhaust pressure of the HP cylinder, even when the point of cut-off in the HP cylinder is kept constant. Seeing that the increased consumption is so marked, it becomes a matter of importance to discover the reason for it. Part can be accounted for by reason of the smaller amount of cushion steam in the cylinder when the back pressure is lower. The clearance spaces are, therefore, not quite so full when admission takes place, and consequently an extra amount is let in per stroke. The explanation generally given for the other increase in the "missing quantity" is that there is an increased amount of condensation due to the greater range of temperature with the lower back pressures. This statement has, however, never been proved by direct experiment.

Messrs. Callendar and Nicolson* have brought forth evidence to show that initial condensation does not play so great a part in the steam consumption of an engine as is generally supposed, and that the greater part of the "missing quantity" is due to direct valve leak. That is to say, part of the steam never enters the HP cylinder, but leaks past the valve directly into the exhaust. The writer has shown by experiment† that this valve leak is directly proportional to the difference between the steam and exhaust pressures. It is, therefore, of the greatest importance to keep the back pressure of the HP cylinder fairly high, and this indicates the necessity for great attention to be paid to the size and point of cut-off in the 2nd cylinder of multiple expansion engines.

The effect that an extra cylinder has upon the horse-power developed is well shown by Plate 7. In this diagram the full

* Proceedings of the Institution of Civil Engineers. Vol. CXXXII., Part 2.

† Proceedings of the Royal Society of Canada, 1896.

lines represent the cards from the 10½in. and 15½in. cylinders in a quadruple expansion trial, and the dotted card is the one from the 15½in. cylinder, when it is used as the IP cylinder in a triple expansion trial. The point of cut-off in the HP cylinder was, in both cases, the same, and the volume at cut off in the 15½in. cylinder of the triple, was practically the same as that in the 10½in. cylinder of the quadruple. We might, therefore, expect the admission pressure to be the same in both cases, but the card indicating the expansion carried out in the 15½in. cylinder alone, shows a considerable loss of area when compared with the cards that exhibit the expansion as carried out in two cylinders. This reduction of area will be probably due in part to increase of condensation due to early cut off, partly to leakage out of the cylinder into the exhaust, partly to wire drawing due to early cut off, and partly to direct leakage from the steam chest into the exhaust.

It becomes then quite clear why the consumption per horse power of the quadruple expansion engine with cylinders 7in., 10½in., 15½in., 23in., will be less than that of the triple expansion with cylinders 7in., 15½in., 23in. It is evident from Plate 7 that the back pressure of the quadruple can be made higher than that of the triple, and, therefore, the steam used per stroke will be less; and, also, that the IHP of the quadruple will be greater than that of the triple. There cannot, however, be much difference between the consumption per stroke of the quadruple and that of the triple with the 10½in. intermediate cylinder, because the HP exhaust pressure is in both cases practically the same. The horse power of the quadruple has, however, been shown to be the greater.

Up to the limiting pressures of these experiments there seems, therefore, to be little advantage in having quadruple expansion engines rather than triples. It must also be borne in mind that the cylinder ratios for the triples experimented with were not at

all good. The ratio between the IP and HP might have been a little larger, and an earlier cut-off in the IP cylinder would have produced the same back pressure in the HP cylinder with probably little or no loss of card area. The ratio between the LP and IP could have been made less, which would tend to reduce the losses due to gaps between the cards, and so an increased horse power might be obtained for the same consumption of steam.

Before concluding this paper, I must state that, in my opinion, with our present lack of knowledge, the adoption of triple and quadruple expansion for increased steam economy is most unscientific. The correct thing would be to find out exactly the cause for increased consumption with decreased back pressure in the HP cylinder. If, as Dr. Nicolson states, this is chiefly due to valve leak, and initial condensation has only a secondary effect, attention should be especially directed to methods of preventing this valve leakage, by the design of suitable valves. This would then enable us to use compound engines for higher pressures, with a greater number of expansions than is found at present feasible.

Further research upon the reasons for the "missing quantity" is, therefore, absolutely necessary; and I would earnestly direct the attention of engine builders towards it as the chief difficulty to be solved before the consumption of steam engines can be reduced by any substantial amount.

DISCUSSION.

Mr. Henry Webb gave some interesting particulars with regard to the working of quadruple engines at the Peel Mills, Bury. The consumption of coal came out at 2⅜lbs. per IHP year in year out, including everything, heating the mills, electric light, &c. The firm were in favour of quadruple expansion engines,

as these had worked to their satisfaction. Personally he had great faith in the merits of a good compound engine at 160lbs. pressure.

The CHAIRMAN read a letter from Mr. JOHN H. STREET (Willans & Robinson), which was to the following effect:—

For comparison with results of trials referred to in Mr. Mellanby's paper I beg to submit the following figures taken from the usual test sheets, compiled from trials of Willans' engines during the last few months. They are from engines of the same size, developing 800 IHP through three cranks.

I may say that our firm's practice (based on the late Mr. Willan's well known experiments) is for pressures of 100lbs. and below, to propose, simple engines, from 100lbs. to 140lbs. compound, from 140lbs. to 200lbs. triple. Beyond this we have not done much and before anything can be done by us or anyone else, the changed conditions of high temperatures will have to be met in respect to lubrication and the deterioration of copper and its alloys, in addition to the mechanical difficulties incident to greatly increased pressures, though there is no doubt that pressures are still tending upwards and quadruple cylinders will come as a matter of course.

I think Mr. Mellanby is hard on engineers for their unscientific methods, and though there are many brilliant exceptions, a good proportion of so-called scientific research is contradictory and unreliable; Lancashire engineers especially are worthy of praise for the amount of useful work done in face of the want of data and against the prejudices of often unsympathetic clients, also considering the risks run in departing from current practice, they have had an insufficient return financially.

If engineering schools could be furnished (either by Government or other means) with the necessary plant to put "theory

into practice," instead of the two extremes of the "rule of thumb" man and the most impracticable theorist, we should have engineers of incalculable value to the profession, and be the best equipment to fight foreign competition, which daily becomes keener.

FIRST ENGINE.

Load.	Pressure in Steam Chest in lbs.	Cut off in 1st Cylinder.	Mean Pressure referred to L.P. Cylinder.	Vacuum in Exhaust Chamber.	Revs. per min.	Indicated horse power per min.	Kilowatts per min.	Consumption of Steam in lbs. of Feed Water per hour. Indicated horse-power.	Electrical horse-power.	Kilowatt.
Full	161	·65	38·81	23·3 in.	270	803·5	476·4	13·88	17·47	23·42
¾	133	·65	32·69	23·2 in.	244	612·5	347·8	14·01	18·4	24·67
½	102	·65	24·06	24 in.	232	425·5	233·1	14·88	20·26	27·17
¼	66	·65	15·78	24·4 in.	221	255	120·8	16·57	26·1	34·98

Triple.—Fixed Cut-off. Cut-off in Intermediate and L.P. Cylinders ·6. Ratio of Cylinders 6·4 to 1.

SECOND ENGINE.

Full	185	·5	37·86	19·2 in.	268	785·6	479·2	13·73	16·75	22·46
½	169	·5	22·25	20·8 in.	267	456	245·7	13·85	19·18	25·71
Full	192	·7	38·75	Non-Condensing	266	791·3	490·3	16·85	20·29	27·2
½	177	·38	21·8	Non-Condensing	268	446·4	240·5	18·8	26·05	34·9

Triple.—Auto. Cut-off. Cut-off in Intermediate and L.P. Cylinders ·6. Ratio of Cylinders 6·4 to 1.

THIRD ENGINE.

Full	174	·55	39·54	22·4 in.	270	818	505	13·52	16·33	21·9
¾	146	·55	32·98	22·8 in.	274	694	413·5	13·75	16·6	22·2
½	121	·55	27·92	23·5 in.	270	620	324·5	14	16·74	22·5

Triple.—Fixed Cut-off. Cut-off in Intermediate and L.P. Cylinders ·6. Ratio of Cylinders 6·4 to 1.

This Engine was also tested as a **Compound**, using the Intermediate as the Initial Cylinder.

Full	198	·6	38·26	22·1 in.	270	793	468·5	16·67	21	28·18

Fixed Cut-off. Cut-off in L.P. Cylinders ·6. Ratio of Cylinders 2·53 to 1.

FOURTH ENGINE.

Full	140	·37	39·61	25 in.	272	827	504·4	15·04	18·4	24·67
¾	137	·24	36·85	25·8 in.	270	638	376	14·35	18·4	24·67
½	123	·1	22·05	26 in.	270	460·6	247·1	14·47	20·13	26·98
¼	105	·1	14·42	26·5 in.	270	293·5	127·4	16·31	28·04	37·58

Compound.—Auto. Cut-off. Cut-off in L.P. Cylinders ·6. Ratio of Cylinders 8 to 1.

Mr. W. H. ATHERTON said: The value of Mr. Mellanby's paper is due, I think, quite as much to the explanations he gives as to the trial results submitted. Many people are content with well-established *facts*, without troubling much about *reasons*. But to the scientific man it is always a pleasure to meet with reasonable explanations of ascertained experimental facts; and the author in explaining *why* the quadruple expansion engine used less steam than the triple, has afforded us this pleasure.

In reading over the paper, the first marginal note I made was this: why don't more engine builders *test* their engines properly, so as to learn all they can from them for future guidance? It is expensive to test engines, undoubtedly, and it takes considerable time; but in the long run it pays a hundred-fold. The engine builders noted for their careful testing, have been brilliantly successful; because they know exactly what their engines can do under specified conditions, and they have studied the precise effect of slight modifications in design and conditions of working. Hence they can lead while others follow. Those firms which neglect to test their engines in a scientific manner will surely be soon left behind in the struggle for supremacy. What folly it is, therefore, to go on making engines indefinitely, without ever testing one thoroughly, and to guarantee steam consumptions by mere guess work, or else by other people's results!

Take, for example, the vexed question of *reheater receivers*. Can any engineer say precisely what amount of benefit may be derived from a given reheater, working under stated conditions? At present, I think, no one can even say with confidence whether it is worth while or not to fit a reheater at all, simply from the lack of careful quantitative experiments. Professor Weighton has made some tests on the Newcastle experimental engines which seem to show that reheaters are quite useless.

And yet expensive multitubular reheaters continue to be specified by consulting engineers and fitted by engine builders.

The next marginal note I made was this: why is a 4-crank quadruple more economical when the HP and 1st IP cranks are set opposite, than when they are set at right angles? Is it because the mechanical efficiency is higher in the former case, due to the reduction of journal load, or is it because the back pressure on the HP piston is greater? Perhaps the author will be good enough to enlighten us on this point.

Turning now to the diagrams: the curves on Plate 1 show very clearly that although, at light loads, the steam used per IHP hour by the quadruple is decidedly less than that used by the triple, yet the steam used per *brake* HP is practically the same, and at a particular load, viz. 40 BHP, there is no difference whatever in the economy of the two types of engines, though the difference per *indicated* HP hour is as much as 2lbs. At still lighter loads the triple would show a *better* economy than its rival per BHP, as may be seen by producing the curves beyond the point of intersection. Thus, while the steam consumption curves on the *indicated* HP basis diverge as the load is diminished, those on the *brake* power basis converge, so that the former are misleading. Hence the importance of comparing the economical performance of engines on the basis of *brake* HP rather than *indicated* HP. In the case of steam dynamos however the most convenient basis of comparison is, of course, the steam used per Kilowatt-hour.

From Plate 2 it is clear that quadruples are certainly more economical than triples at high pressures, but less economical at low pressures. This again does not appear from the water per IHP curves, but only from the curves representing the steam consumption per brake horse-power per hour.

From Plate 3 we notice that the mechanical efficiency of the quadruple is less than that of the triple, at all loads. This is

not surprising; but the rapidity with which the efficiency of the quadruple falls off as the steam-chest pressure is reduced, compared with the slowness of the other, is very remarkable, and calls for some explanation. It seems incredible that the friction of the extra parts should account for *all* the difference shown.

No mention has been in the paper of the actual commercial performances of the 5-crank quadruples designed by the late Mr. Thos. Mudd, of West Hartlepool, though Mr. Mellanby is well acquainted with them. A comparison between the results given by these engines and by ordinary triples would be interesting. Comparatively few ships, as yet, have been fitted with quadruples, the most notable being the famous Hamburg-American liner "Deutschland," which holds the record for speed. These are the largest engines in existence, the power of each set being about 18,000HP, and they appear to be a great success.

Referring to the subject of valve leakage, I should like to ask Mr. Mellanby does the statement he makes in reference to slide valve engines, that the missing quantity is chiefly due to direct valve leak, apply equally to engines fitted with separate steam and exhaust valves, (such as those of the Corliss and the double-beat type) or is this one of the questions to be settled by experiments on the new and unique Manchester Technical School experimental engines?

To builders of mill engines, also electric light and traction engines, the choice is not at present between triple and quadruple expansion engines, but between triple and compound; and experiments are much wanted to determine the relative economy of these at all loads, each engine being designed with the most suitable cylinder ratios, and using steam at the same initial pressure. Electrical engineers would also like to know the respective performances of well-designed compound and triple

expansion engines, when the load fluctuates from 20 to 50% every few seconds, and when run under non-condensing as well as condensing conditions.

The present trend of mill-engine construction is undoubtedly in the direction of compound engines working at 160 lbs. per sq. inch, on account of their relative simplicity, cheapness, compactness, and high mechanical efficiency compared with triple expansion engines. Of the numerous engines recently built for electric traction work, it is certain that very few are triples and not one is a quadruple. The question of the constancy or the variableness of the load has an important influence in determining the best type of engine for a given purpose, and a compound is certainly better than a triple for a very variable load, such as is common in traction work. But there is this mechanical or constructive objection to compound engines, that the initial load on the parts is greater than in the case of a triple or a quadruple of equal power, using steam at the same pressure; and the turning moment is also not so good.

In conclusion I believe that quadruple expansion engines are the engines of the near future for high-powered merchant steamships, run usually at full speed, and they are also very suitable for large electrolytic units, which run for months at a time without a stop, and at full or over-load. But for warship engines, also for mill-driving and for lighting and traction work, we are not yet within measurable distance of their extensive adoption.

Mr. James Saxon said he agreed with the author as to the comparative uselessness of experimental engines generally for research purposes, but a notable exception was that of the engines at Newcastle, which he had visited along with the Chairman and Director of the Technical School some time back. It was not, however, ordinary college engines to which

they had to look for searching investigations of the mysteries perplexing engineers, but rather to an educational awakening throughout the country as to the benefit and necessity of increased technical education. He believed people were gradually awakening to this, and prepared to pay a good sum to have proper equipment in technical schools for carrying on experiments, in order that our knowledge might be increased on such points as had been brought before them that night. He believed they were going to have at the new Manchester Technical School an up-to-date engine which would enable Dr. Nicolson, Mr. Mellanby and others to conduct valuable experiments for the benefit of both engineers and the city generally. The experiments described showed the quadruple engine to be more economical than the triple. They had previously had this knowledge, roughly, from isolated tests by makers and others. The mechanical efficiency of the triple engine, or the difference between the brake horse-power and the indicated horse-power was, however, shown to be better than that of the quadruple engine. This was probably owing to the greater multiplicity of the parts in the quadruple, causing greater friction, &c. Then again, there was the greater cost of the quadruple to consider. For mill and work's purposes, therefore, it would be best to put in triple in preference to quadruple engines, taking all these points into consideration. As to the reasons for increased consumption by lowering the back pressure in the high pressure cylinder, Dr. Nicolson and Mr. Mellanby might readily test the valve leak theory if they had an experimental engine made with modern Corliss or Sulzer valves. That is, Corliss or Sulzer valves with separate steam and exhaust valves and ports, instead of the simple slide valve with which the experimental engines referred to were fitted. With the separate Corliss or Sulzer valves the leak would be possibly done away with, or in any case minimised, and the

amount of it could be ascertained. As to the comparative merits of the quadruple and triple expansion engines, there were evidently other reasons in the author's mind than those mentioned in the paper, or else he would probably have made some definite assertion that quadruples, and nothing but quadruples, should be the order of the day with engineers. There was no doubt the simpler engine was the best to adopt in practice unless the advantages of the more complex type, from an economical standpoint, were overwhelming. As to the "missing quantity," he would again advise the author to go a little further, and test the point with another type of valve than the slide valve, with which the experiments had been made.

Dr. J. T. Nicolson said he felt it to be a duty as well as a great pleasure to express his appreciation of the high value of the results recorded by Mr. Mellanby in his paper that evening. He considered he was probably in a better position than any member present to realise the enormous amount of work involved in the making, recording, and working out of the long series of progressive trials of which only a partial outline had been given them by Mr. Mellanby that night. He had had the pleasure of being associated with Mr. Mellanby at McGill University in 1896, when the latter went to Canada as an 1851 scholar of the Durham College of Science, to make a research with the quadruple expansion engines in his laboratory there. At that time those engines, which had been built by the Lancashire firm of Messrs. Yates & Thom, and the engines at the Newcastle College of Science, were the only quadruples in existence which had been built for the sole purpose of research. Mr. Mellanby began his researches under his direction at McGill, and continued and completed them with conspicuous success at Newcastle. It was a short paper which had been

presented to them, and it hardly gave a hint of the labour which underlay it, as the foundation of the conclusions stated. In the tests carried out, as they had been carried out, at McGill College, the engines fairly bristled with thermometers, indicators, and gauges; the observers, numbering from 15 to 20, each took down four or five readings every five minutes; and when he told them that all the resulting figures had to be checked, and averaged, the more important plotted to guard against errors; and that the three or four score of indicator cards were not merely plani-metered, but ruled with ordinates at 10 breadths, each ordinate measured and entered on result sheets, and a mean card for the trial thereby constructed for each end of each of the four cylinders, they would begin to see that to carry out a series of 30 or 40 such trials was, to put it mildly, a serious undertaking.

Of the many problems Mr. Mellanby set them in his paper, the one which interested him (the speaker) most, was the accounting for the fact, that with the same initial pressure, revolutions, and cut off in the HP cylinder of a multiple expansion engine, the quantity of steam or water used per hour would vary considerably on different trials when the back pressures in the HP cylinder differed.

He had obtained from Mr. Mellanby the data necessary to obtain results given in the following tables which contained figures from the trials made by him on the McGill College engines. These engine were of the double tandem vertical marine type, with cylinders 6½in., 9in., 13in., and 18in. diameter (numbered I., II., III. and IV. respectively); all of 15in. stroke. All the trials here cited were run at about 90 revolutions per minute.

In this table were presented certain results for the high pressure (No. 1) cylinder only, from ten trials; the first six of which (28, 29, 43, 41, 31, and 30), were made at an initial

TABLE A.

1	Trial No...	28	29	43	41	31	30	35	33	39	37
2	Conditions	T U	T J	T J	T U	C J	C U	Q J	Q U	T J	T U
3	Expansions, No. of	12·3	12·3	12·3	12·3	12·3	12·3	22	22	22	22
4	Cylinders Used	1,3,4	1,3,4	1,2,4	1,2,4	1,4	1,4	1,2,3,4	1,2,3,4	1,2,4	1,2,4
5	Pressure Range	88·4	96·2	76·6	76·3	118	127·6	131	136·3	132·2	141·5
6	Temperature Range	60·3	67·7	47·4	50·4	90·7	110	75	79	76	86
7	Initial Temperature	365	364	367	365	364	363	386	387	383	386
8	Missing Quantities per hour in lbs.	175	195	146	151	267	295	197	230	268	271
9	Condensation Limit	56	62	44	46	84	105	69	73	71	79
10	Leak per hour	119	133	102	105	183	190	128	157	197	192
11	Steam Supplied to Steam Chest per hour...	820	830	802	788	935	995	691	705	733	756
12	Leakage Co-efficient for Cylinder No. 1 ..	1·34	1·39	1·34	1·37	1·55	1·49	1·0	1·15	1·49	1·35

pressure of 155 lbs., and with 12·3 expansions. The trials marked T were triple, and C compound expansion trials; U and J meaning unjacketed and jacketed, respectively. *In all these ten trials, however, the high pressure cylinder* (*No. 1*) *remained unjacketed;* so that the valve leakage was comparable in all. The fifth line gave the difference between the pressures in the steam chest and exhaust pipe of No. 1 cylinder. Lines 8, 9 and 10, gave missing quantity; the greatest quantity of condensation that it was possible to have, and the leak; all estimated as described below. Line 11 gave the steam used per hour, exclusive of all jacket steam; and line 12 gave the result of dividing the figures in line 10 by those in line 5.

The last four trials (35, 33, 39 and 37), were made at 205 lbs. gauge pressure, and with 22 expansions, so that the cut off was earlier in the HP cylinder than for the first six trials.

Although the pressure of the steam at cut off in the HP cylinder and the volumes of such steam contained in the cylinder at cut off in the first six trials was practically the same, they give (v. line ii.) the very considerably different amounts which the engines used per hour on different trials.

Mr. Mellanby had invited him to speak on this question by mentioning his (Dr. Nicolson's) name near the end of his paper, where he had, so to speak, thrown down the gauntlet to him, to prove that these differences were due to valve or other leakage.

He would, therefore, endeavour to give evidence that leakage was largely responsible for the observed effects; but he regretted he could not do so, by the aid of the datas and diagrams given in the paper as certain fundamental datas, such as the missing quantities, and the drawings of the engine cylinders and valves were wanting.

He could, however, take the necessary datas from the trials made by Mr. Mellanby on the McGill engines from the paper

he had published in the transactions of the Royal Society of Canada.

He would begin by refreshing their memories as to what was meant exactly by the missing quantity. If, in the mean indicator diagram of trial, they took any point after cut off and estimated the volume the piston had swept up to that point, added thereto the clearance volume, and divided the sum by the volume per pound of the steam at the pressure of the point in question, they would obtain the weight of steam at that instant accounted for by the indicator, usually called the indicated weight. The difference between the weight actually supplied to the HP steam chest (as measured by the weight of water discharged from the air pump) and the indicated weight at any point of the expansion line was (neglecting cushion steam) the missing quantity. These calculations had been made by Mr. Mellanby in the case of the McGill trials for a number of points on each expansion curve, and the results plotted as shown in the diagrams of that paper.

He would, therefore, take these missing quantities and endeavour to account for them. It seemed clear that the quantity of steam not shown by the indicator, was either (*a*) present in the cylinder in the form of water suspended in the steam, or adhering to the walls, or (*b*) absent from the cylinder altogether, having really not entered it at all at admission, but having leaked across the valve faces into the exhaust pipe.

If then, they could actually measure either of these quantities (*a*) or (*b*) separately, they could infer the value of the other.

An attempt had been made to experimentally determine the amount of cylinder condensation by Professor Callendar (formerly Professor of Physics at McGill College), and himself; by the use of thermo-electric junctions and thermometers in the cylinder walls. The amount of heat received and rejected

every stroke by the metal surrounding the steam had by these means been measured, and the quantity of steam which would have to be condensed and re-evaporated at every cycle in order to account for the observed changes of wall temperature had been calculated. Time would not permit him to go fully into the matter that evening; but he would present three copies of Prof. Callendar's and his paper (Proc. Inst. C.E., Vol. cxxxi., Part I. Sess. 1897-98), to the library, so that any member could examine the evidence for himself.

He would merely show the application of their method to the calculation of the amount of cylinder condensation in any engine in which the average wall temperature could be measured by inserting a common thermometer in a hole in the cylinder covers. If they took the indicator card and plotted from it, by reference to steam tables, another card with temperatures of the steam for ordinates and piston travel or volume for abscissæ; and if they then set out the various ordinates of this temperature card on a base of crank angles, they would get the temperature cycle card shown on Fig. 1, Plate 8.

If, now they drew a horizontal line across this figure at a height corresponding to the mean temperature of the cylinder-clearance walls, the area shown shaded above this line would represent to a certain scale the weight of steam condensed up to cut off on those walls. Further, it had been shown by them, that under no circumstances could a greater amount of steam be condensed in a cylinder than that corresponding to the shaded area obtained in this way.

If they had not the wall temperature, but knew the admission and exhaust steam temperatures and diameter of the cylinder in question, then they might make a roughly correct estimate of the greatest amount of condensation which could take place per hour in the cylinder by multiplying the temperature range by four times the area of the cylinder in square feet, or

$$\text{Condensation limit} = \pi d^2 (t' - t'') \text{ lbs. per hour.}$$

where d = diameter of cylinder in feet.

t' = temperature of admission steam.

t'' = temperature of exhaust steam.

The results of this calculation, made for ten of the McGill College engine trials, were presented in line 9, of Table A, above; and in line 10 were given the amounts of leak obtained by subtracting the estimated limiting condensation from Mr. Mellanby's missing quantities.

He (Dr. Nicolson) had plotted these missing quantities, and the leaks so obtained for all the trials as ordinates on a base of pressure ranges; and had shown them on the accompanying diagram. Fig. 2, Plate 8.

It was clear from this diagram that, in the case of the trials, at an initial pressure of 155 lbs., both the missing quantity and the estimated (minimum) leak followed an approximately linear law in relation to the difference of pressure between the steam and exhaust sides of the slide valve; and this lent strong support to the view that the leakage of steam past the slide valve was a factor of at least as much importance as cylinder condensation in regard to the steam supplied to the engine which was not accounted for by the indicator. It ought further to be remembered that the cylinder wall temperatures were not observed in these trials; that the cylinder condensations assumed in the estimations here given, were the greatest that could possibly have taken place; and that from evidence obtained on other trials, it was almost certain that the amounts due to this cause were considerably smaller, and *were independent of the pressure or temperature ranges.* This was due to the fact that the condensation was probably partial. (Comp. Callendar and Nicolson, page 192) that re-evaporation was completed before release, and was therefore unaffected by the amount of back pressure.

In the case of the four trials at a pressure of 205 lbs. per square inch, the law was not maintained; but to explain this, they had only to remember that the cut off was much earlier than in the first six trials, and that the Ryder (or Bodmer) cut off valves would have changed not only their lengthwise, but also their transverse position with reference to the main slide valve; which probably gave rise to some change in the shape of the narrow cranny through which the steam had to leak.

Mr. William Heap said the question to the ordinary consumer was, "Will it pay to have triple, quadruple, or compound engines?" They would ask whether any extra economy in working in favour of the quadruple would or would not be counterbalanced by extra initial outlay, interest on capital, depreciation, repairs, &c. With regard to the engines mentioned by Mr. Webb, he would like to know whether the indication diagrams had been taken at the average load.

Mr. Webb said the load did not vary in a textile mill. They span the same thing year in, year out.

Mr. E. G. Constantine observed that in the large number of experiments which had supplied the data for the paper, the effect of jacketting or not jacketting would no doubt have been taken into account. The vexed question of jacketting had not by any means been definitely settled. Prof. Weighton was considered by many advocates of jacketing as somewhat of a heretic on the subject of jacketing. He did not know whether Mr. Mellanby partook of Prof. Weighton's views or not. Perhaps he would tell them in his reply.

Mr. R. Gregory said the firm he was connected with had made several trials with triple and quadruple engines, and with triples got to as low as 11¼ lbs., but had never come down below

12 with the quadruple. They had come to the conclusion that the triple was the more economical engine of the two. His own impression, however, was that the compound engine at 160lbs. pressure, or up to 180 lbs., would work as economically as either the triple or quadruple, though he could not speak from tests.

Mr. George Dixon (Hick, Hargreaves & Co.) said that some years back a single cylinder non-condensing engine by Musgrave's, with Corliss valves, 18in. diameter, 3ft. stroke, running at about 80 revs. per minute, was tested soon after setting to work by Prof. Kennedy, and the steam consumption was 30½lbs. After the lapse of twelve months it was tested again, after everything possible had been done to make the valves and piston tight, and the steam consumption was almost 26lbs. He put the entire difference down to leakage. Experience went to show that the compound engine at high pressure was quite as good as the triple, as the mechanical efficiency was higher. If superheated steam was used the result was still more in favour of the compound.

He believed in a thorough system of jacketting, and taking the whole of the steam round jackets and into the cylinders. It had been said that steam passed round in that way must be wet, but might they not assume if that steam was carried round as it was in jacket they used that it might also prove a separator, so that the steam did not enter the cylinder any wetter than if it had not gone round the jacket, and of course the work done by that steam was much greater.

Mr. Philip Robson said it was important to note the point mentioned by the author about considering the two points of horse power and water consumption of the engine separately. He would like to have some information about the condition of

the intermediate receivers from the point of view of draining. If he remembered rightly Prof. Weighton's work, he found a very considerable difference in the total consumption when he carefully drained the receivers between the cylinders. If there was anything in the leakage theory, he thought that point was of some importance. Dr. Nicolson had pointed out that he assumed the leak to take place in the form of water, and therefore from that point of view, it appeared that the leakage could be greatly reduced if the steam were kept dry, and upon that point perhaps Mr. Mellanby would give them some additional information. The point was, he considered, of some importance in respect of the introduction of superheated steam that was now going on. They wanted to understand more clearly to what the precise increase of efficiency obtained by superheating was due. Was it simply because the valve leak was lessened, or was it due to the extra heat put into the steam?

Mr. Alfred Saxon said the figures given by Mr. Webb for the quadruple engines compared unfavourably with results he could give them for compound engines, which developed greater horse-power with less coal consumption. With regard to the testing of engines by makers, it was very difficult to test large engines experimentally, but if a research committee were appointed he for one would do all in his power to forward its work for experimenting on some of these large engines. With regard to high back pressure proving economical, he had had some experience which seemed to go against that view. In some engines they had converted from compound to triple expansion, they found that as the valves were set the initial strains on the two engines were very unequal. They equalised these somewhat by allowing the valve gear on the intermediate cylinder to trip off very much earlier, and thereby obtained a higher back pressure. After that alteration the coal consumption increased.

Some time afterwards the engineer of the place where the engines were working told him he had altered the valves of the intermediate cylinder to carry on later and reduced the back pressure, and the result had been to effect a considerable saving in coal, although it had upset the equalising of strains. It would be interesting to prove one or two of these points by tests on a large scale. The author's experiments seemed to go a long way to prove much that he had suggested as arising out of the trials. He thought they could get, as an Institution, the use of some of the large mill engines in order to make distinct trials, with a view of proving or otherwise some of the theories that had been advanced that night. As he had said, some of his experience had gone directly in contradiction of the author's view as to back pressures. In large cotton mill engines there was a limit to early cut-offs in the intermediate or succeeding cylinders, on account of the manner of getting the power out. With regard to Dr. Nicolson's experiments he would like to ask whether he got the amount of steam actually in the cylinder that he assumed, or whether it was wire drawn.

The CHAIRMAN (Mr. Henry Webb) said that however much importance they attached to experiments like those conducted by Mr. Mellanby—and their importance could scarcely be over-estimated—they must not forget that they were conducted under the most favourable conditions, differing greatly from those obtaining in actual practice. The proper course was to take them as a basis for improving actual practice.

Mr. WALTER M. REDFEARN in a written communication said: I have read the advance copy of Mr. Mellanby's paper with interest, and it has suggested the following remarks to me.

Are we going in the right direction for ensuring economical consumption of steam by expanding it through a series of three

cylinders, as in a triple expansion engine? Can the same economy be effected by expanding it through a series of two cylinders, as in a compound engine, having a ratio equal to the ratio of low pressure to high pressure of a triple expansion engine? This view of the question has received attention in the United States by Geo. J. Rockwood, and is known as the "Rockwood" system of compounding.

He proposes a boiler pressure of from 160 to 180lbs. per square inch, cylinder ratios of about 8 to 1, and terminal pressure of about 8lbs. per square inch. Of course by this arrangement there are a greater number of expansions in each cylinder than are generally used, but, according to Professor Thurston, there is no greater loss from cylinder condensation due to the increased range of temperature in the "Rockwood" system than the loss under the less range of temperature of ordinary triple or compound engines. At any rate, the real point which decides the efficiency of a system is the steam or water consumption, and from independent tests this system appears to show up very well indeed in this direction.

From tests made by Geo. H. Barrus, Boston (U.S.A.), and published in *The Engineering Record* of 20th November, 1897, the steam consumption was found to be 11·8lbs. per IHP per hour. The tests were made for the Grosvenor Dale Mill Co., and the engine was a cross compound factory engine of the "Rockwood" type, having cylinder ratios of about 7 to 1 and at time of test the boiler pressure was about 150lbs. per square inch, and engine was turning 660 IHP.

In the case of another compound factory engine of this type (an epitome of which test may be seen in a list of trials selected by Bryan Donkin, and published in the *Engineer* of some time last year), a result of 12·74 lbs. steam consumption per IHP per hour was obtained, with cylinder ratios of 7 to 1, 159lbs. square inch boiler pressure, and turning 595 IHP.

This is a good field for experimental research for those having the necessary facilities, and is a phase of the subject that is, by no means, overburdened with data. If we can gain practically the same economy with the 2-cylinder engine, why go in for the 3-cylinder triple expansion engine, with its increased friction, maintenance and repairs, and first cost?

Mr. MELLANBY, in replying to the discussion, observed that the quadruple expansion engines mentioned by the Chairman, did not compare very favourably with the ordinary triple expansion marine engine. This type of engine rarely consumed more than 1·5 lbs. of coal per IHP per hour; but probably the engines mentioned by the Chairman were using an inferior quality of coal.

The tables of results given by Mr. Street were extremely interesting and valuable. They were an evidence of the far-sighted policy of Messrs. Willans & Robinson in making engine trials; a policy which had, he daresay, a great influence in bringing them to the eminent position they now occupied. He had no more sympathy than Mr. Street for "so-called" scientific research. With Mr. Street's final remarks he was in entire agreement, and pointed out that one of the objects of the Manchester Technical School was to furnish such experimental plant as he indicated.

Mr. Atherton's remarks showed an almost flattering amount of interest in the paper. His question about *reheater receivers*, opened a much discussed subject. Professor Weighton had informed him that experiments he had made showed that these reheaters were of little or no use. The consumption of steam in terms of the IHP was slightly lowered by using a reheater, but, at the same time, the mechanical efficiency of the engine was also reduced. This showed the importance, when making experiments with interheaters or superheated steam, of giving

the results in terms of brake or electrical horse-power. In reply to Mr. Atherton's question about valve leakage, he would say that he was inclined to think the superior economy of corliss engines, and also engines fitted with drop valves, was due to the fact, that in such engines, the valve leakage would be less than in slide valve engines.

He heard with pleasure, Mr. J. Saxon's remarks about the engines at the Durham College of Science. He hoped that they would soon be in a position to make tests similar to those indicated by Mr. Saxon upon the experimental engines at the Technical School.

Dr. Nicolson's remarks were a valuable addition to the paper. They emphasised his own statements as to the large amount that was yet unknown of steam engine working, and showed clearly, that in order to make much progress in steam engine design, the question of valve leak should be definitely settled.

Mr. Constantine brought up the question of jacketing, but that was a subject upon which no one, as yet, was in a position to give a dogmatic opinion. A long series of trials would have to be made in order to give any real information. Up to now, many isolated trials had been made upon various engines, but owing to the non systematic manner in which they had been carried out, the results they gave were almost valueless for comparative results. If the "missing quantity" was due to valve leak, then jackets would have very little effect upon its amount. Probably they might help to heat the valve faces by conduction, and so tend to reduce the leakage. Dr. Nicolson had pointed out, that if jackets were to be used for reducing the amount of condensation, then the cylinder ends ought to be jacketed, rather than the barrels.

In reply to Mr. Robson, he would say, that for the trials given in the paper, the intermediate receivers of the engine were all drained. Experiments he had made, showed that the

economy of engines was greatly increased by draining the receivers. Mr. Robson's remarks as to the reasons for the increased efficiency due to superheated steam, were deserving of close attention.

He thought Mr. Alfred Saxon's suggestion, that a committee be formed for testing engines was admirable, and ought to be carried out. He could quite understand that the engine instanced by Mr. Saxon, would give better results when the cut off in the intermediate cylinder was made later. He had made a long series of experiments some years ago, which showed that there was a best point of cut off in the cylinders, other than the high pressure one, of every engine. The point of cut off depended upon the ratio of the cylinder to the one that preceded it. If an earlier cut off was adopted than this best one, the steam used per stroke for a constant cut-off in the high pressure cylinder was reduced, but at the same time the horse-power was also reduced. A reference to the diagrams shown in Plate 7, would help to make this clear.

Mr. Redfearn suggested that compound engines with a large cylinder ratio be adopted, but he thought that if the paper proved anything, it proved that such an engine could not be economical. It would have a low back pressure in the high pressure cylinder, and consequently a large consumption of steam. He had, however, made careful trials on compound engines with large cylinder ratios, in Montreal, and found that they were very inefficient. Professor Weighton had also made similar trials at Newcastle, with much the same results.

Before concluding, he wished to thank the members for the interest they had taken in the paper, and to express the hope that he had helped to convince engine builders that there were yet a great many problems connected with the steam engine, that could only be solved by scientific experiment.

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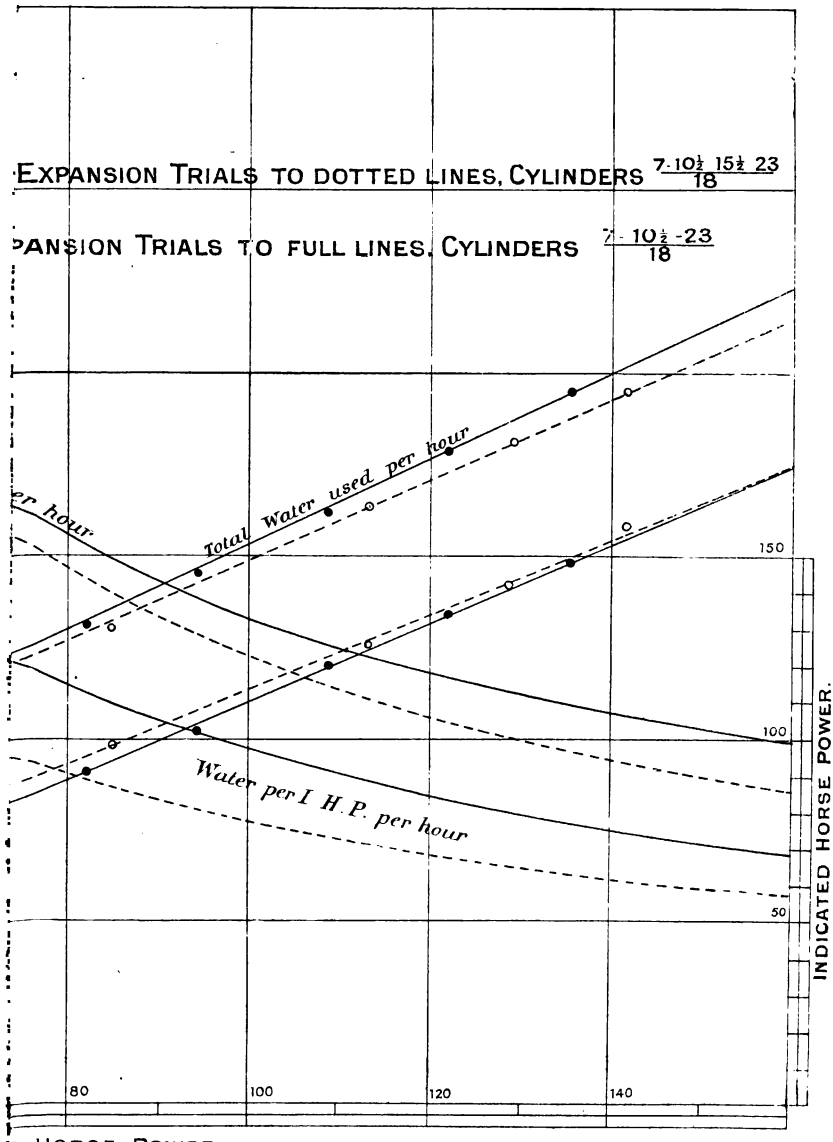
8 Plates follow illustrating this Paper

Plate 1.

,E AND QUADRUPLE EXPANSION ENGINES.



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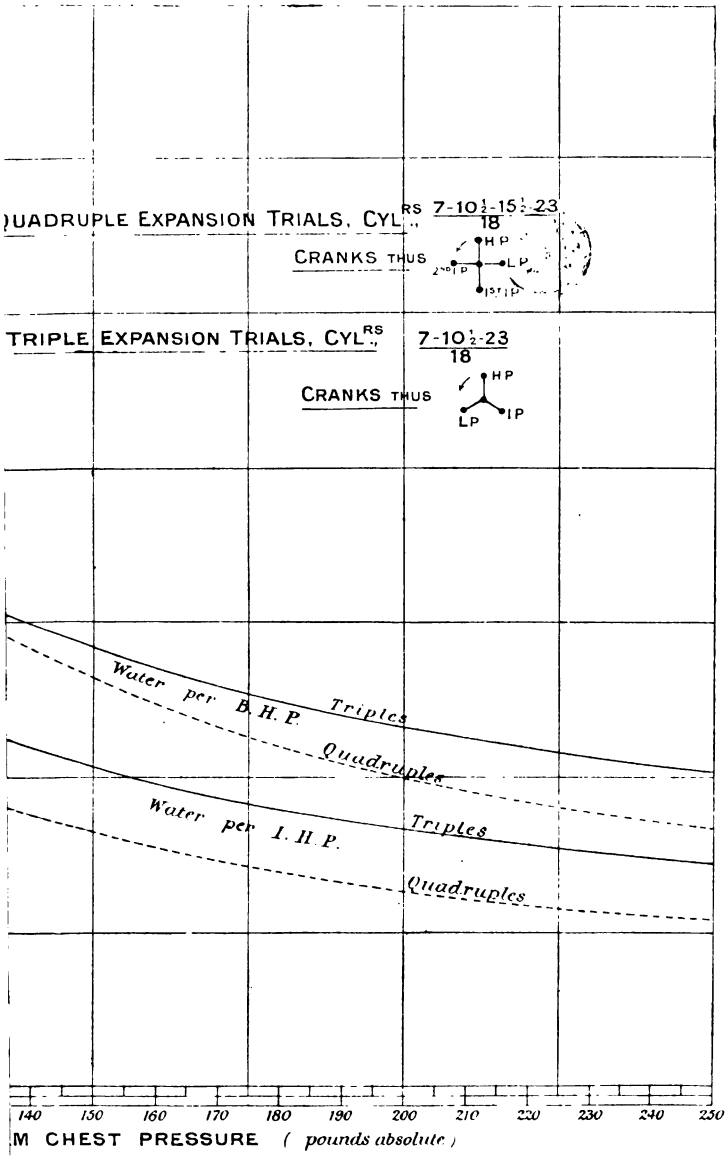
PLE AND QUADRUPLE EXPANSION ENGINES.



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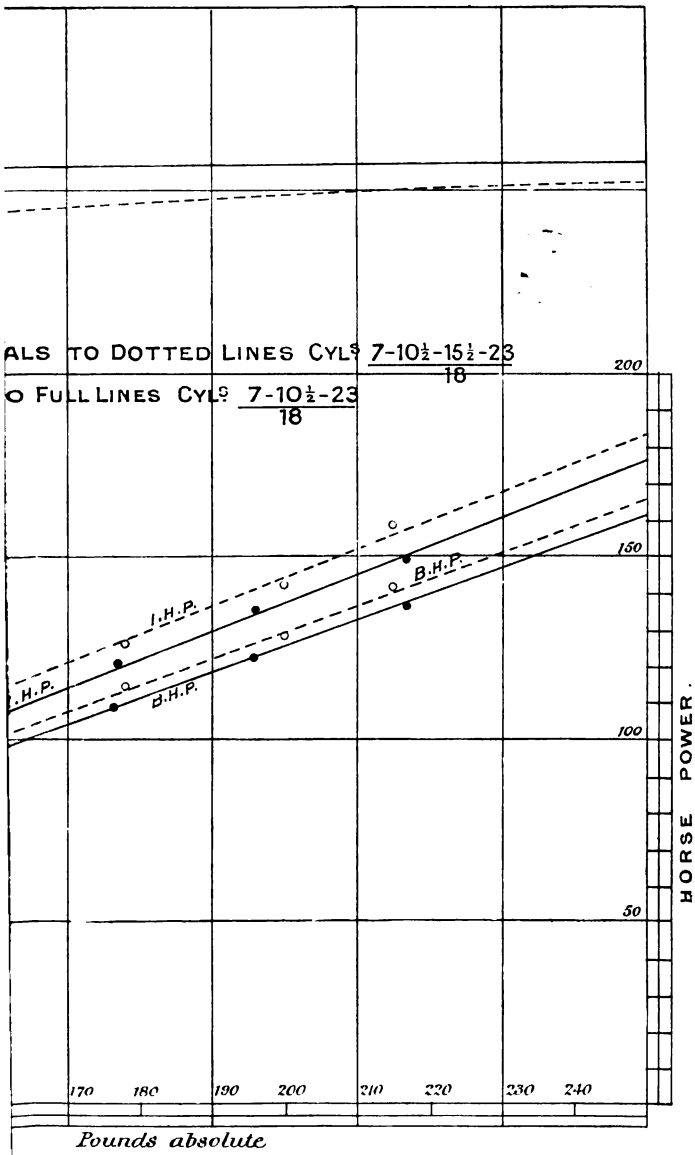

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RUPLE EXPANSION TRIALS.

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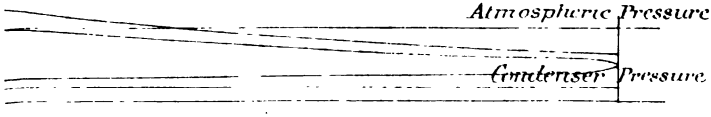

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Plate 5.

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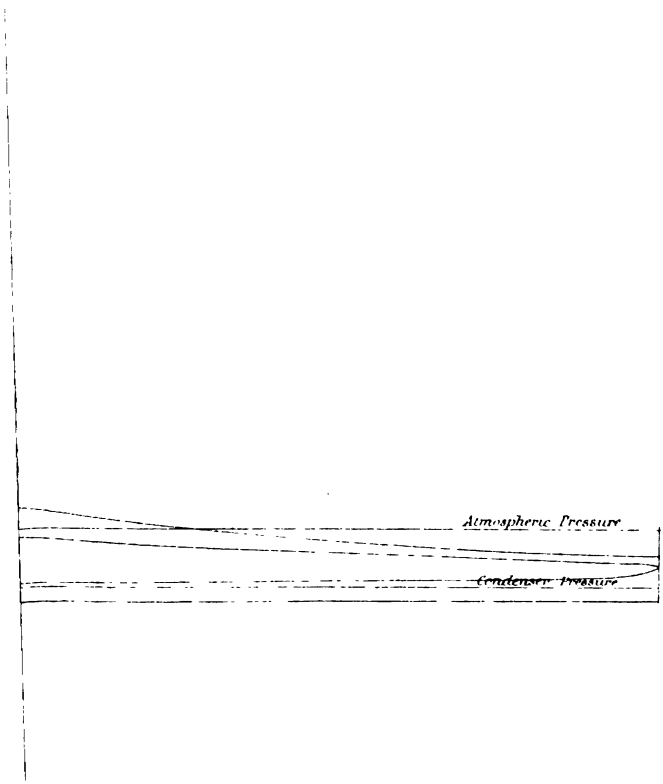

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Plate 6.

ID QUADRUPLE EXPANSION ENGINES.

EXPANSION TRIALS.

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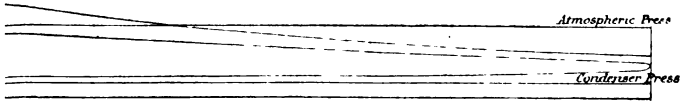

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Plate 7.

PLE AND QUADRUPLE EXPANSION ENGINES.

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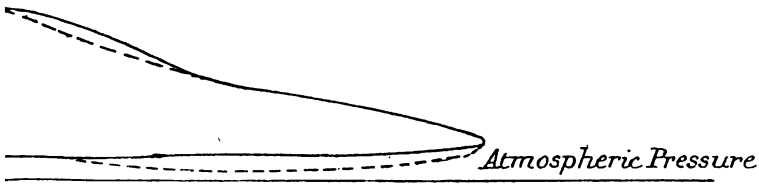

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LATIVE EFFICIENCIES OF TRIPLE AND QUADRUPLE EXPANSION ENGINES.

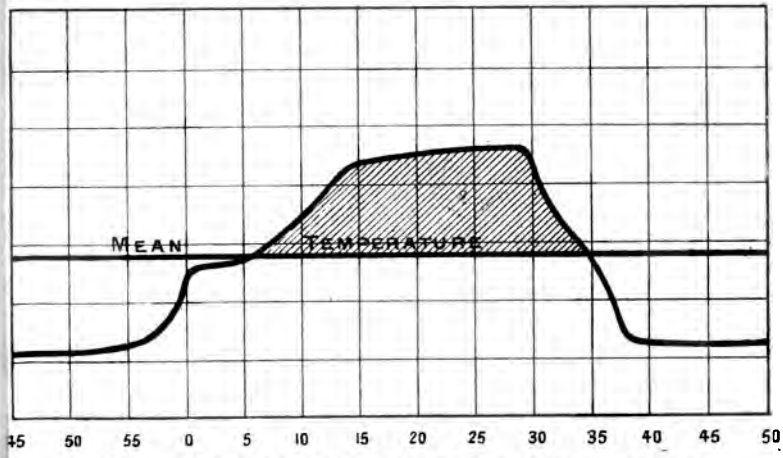

FIG. 1.

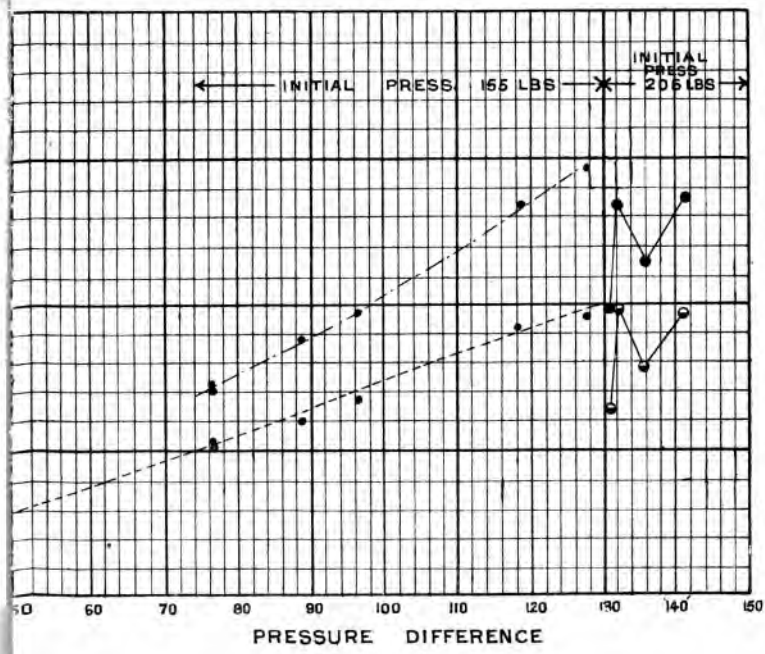

FIG. 2.

HOME LIBRARY

PARIS EXHIBITION, 1900.

DISCUSSION.

SATURDAY, NOVEMBER 3RD, 1900.

Mr. T. ASHBURY thought the engineering construction and architectural design displayed in the Paris Exhibition fully sustained the reputation of the French for beauty and elegance. With regard to the exhibit of "thermite," mentioned by Mr. Webb, he understood it was now sold commercially in Germany at a cost of about 9½d. per lb. The five papers submitted to the members had dealt very ably with the subjects treated, but they necessarily left many branches of the Exhibition untouched.

In connection with the locomotives at the Exhibition, although out of about 60 shown only a small proportion came from England, yet this country had maintained her prestige in regard to this department perhaps more than in any other. Some of the engines exhibited by various railway companies showed the latest developments of locomotive practice in its highest and best form, and were worthy of great credit. Many of the Continental exhibits were very elephantine in appearance, and he was afraid that beauty and simplicity of design was at any rate not the leading feature of the Continent, though the complicated and diversified systems of gear showed great ingenuity. In electric railway locomotives, however, there was an exhibit by the Creusot Co. which showed a startling advance in this direction.

With regard to the group of education, he was struck with the completeness with which all stages, including legislation, organisation, general statistics, plans, models, buildings, equipment, and apparatus, were illustrated. All the countries of Europe and the United States had contributed special

and important exhibits. From what he could gather, other countries had much to teach, but careful examination showed that England was not so far behind as some people would have them believe. When he visited the Exhibition he could not help thinking of the great Hyde Park Exhibition of 1851, when the magnificent exhibits shown by England caused amazement to visitors from other countries. At that time a steel ingot of about 1½ tons, produced by a Sheffield firm, was considered a marvel, but at the Paris Exhibition there was a wooden model of a 150 tons ingot by the Creusot Company. Comparing our position then, as indicated at the 1851 Exhibition, and now, as indicated at Paris, relative to foreign nations, he could not help feeling sick at heart; it was so disparaging to this country, the only compensation being that, whilst they showed their very latest and best, we were only sparsely represented, many well-known firms being conspicuous by their absence. This apparent superiority of our foreign competitors did not imply that England had gone back, but that she had been slow, sluggish, and non-progressive. They were at one time a long way behind, but now had not only come up to her, but in many cases, outstripped her in the race. In certain branches of engineering they had secured a great reputation by pioneering new methods, while we had been content to plod on in the old grooves.

We changed our standards slowly, and were so wedded to old systems that ought to be superseded by new methods, that we failed to use the power at hand, while our competitors evolved new ideas, and developed men and experts who brought to the problems before them a special and peculiar intelligence that was only occasionally found in our midst. There was also too often in this country a lack of personal interest on the part of the workman in the success of the work in hand. We must not, however, be disheartened. We had been careless, and

resting on our oars and content with past achievements; but we had now been aroused, and must put into lively exercise the virtues that had served us so well in the past.

Mr. HANS RENOLD said that although not an Englishman by birth, he had the progress of this country quite as much at heart as anybody. Having seen, perhaps more than many here present, what our foreign competitors was doing, he hoped he would be excused when speaking somewhat freely what he thought about these Paris exhibits. The more so would he like to do this because he had long felt that in this country far too much secrecy was made about everything connected with trade matters. Nothing was more pleasing in this respect than the openness with which one was received in most of the workshops in America. Information there was given and ideas were exchanged with a freedom of which we have little conception of in this country, but if we were to adopt it, would make us all the gainers.

With regard to the Paris Exhibition, there were quite a number of points he had made it his duty to investigate during his several visits there. As the subject of the present discussion was the metallurgical exhibits he would like to say a few words about those materials he was specially interested in. Such, for example, as very accurately hard drawn steel wire, soft wire rods as used in automatic screw machines, steel strips of exceptionally high tensile strain, also strips made by the Bessemer basic process, which as was well known gave the best and most regular case-hardening results. Even such goods as common steel hoops did not escape his attention, for in this article only ten years ago Lancashire did still a large trade with America, whilst to-day the table had completely turned, and imported American hoops could be bought here in Manchester considerably cheaper than home made.

Visiting the English metallurgical section, one could not but be ashamed of our small display made, although what was shown was fair in quality. Being fairly familiar with what Sheffield, the Black Country, Lancashire, and the North-east coast could produce, he could find nothing new or of special interest in above-mentioned lines. Quite different was it in the Swedish, German, American and French sections, although the products of those countries were not altogether unknown to him. As it is only natural the French section was by far the largest, and showed some wonderful specimens of metal rolling, drawing, forging and pressing. Whilst the French display was large and particularly well shown, the prices he thought were not "in it."

The palm among the sections undoubtedly belonged to Sweden. It was the only section completely finished at the day of opening, was very tastefully arranged, very instructive, so that one could with a few morning visits take in what Sweden was capable of producing from one end to the other of that huge country. All praise was due to the Commissioner who had this section in charge, and so well represented the different exhibitors. Sweden was rich in good ore, charcoal and lime, but as to coal, mines only 10% of its wants, the other 90% coming mostly from England. Mr. Renold had in his hand a pamphlet published by one of the largest Swedish exhibitors, which gave some particulars of the extent of their business operations. Reading from that pamphlet, it stated that the Company started mining in 1225, a timber trade in 1689, iron mining in 1738, gold and silver mining in 1790, steel making in 1871, paper and pulp making in 1894.

The German section was also very good in regard to quantity, quality and novelties. This section showed unmistakable signs of a vigorous, enterprising, and independent thinking industrial life. A particular display of small and large steel wire ropes

or cables attracted Mr. Renold's attention. Their particular merit was great relative strength and flexibility, great durability and power to resist the corroding influence of the atmosphere, whilst their surface was almost as smooth as a turned shaft, which in large cables especially was very unlike the ordinary make. On the Continent these German cables were now largely used, and well they might, for Mr. Renold knew, to mention only one, of many Swiss mountain railways which had been converted from a non-paying into a paying concern by using these ropes instead of the old kind. The rope used on that particular railway was 9,150 feet long, ascending a height of 1,835 feet. This German cable was guaranteed to last eight years, whilst the ordinary make formerly used lasted only just a little over one year. The construction and workmanship of these steel ropes involved nothing but what could be done in England, *if*, yes, *if* only we would make up our mind to do it; that was, take more conscientious care in selecting the ingots for the wire rods—would most carefully work out in the drawing office the different rod sections of the various layers which form the cable—would exercise the greatest care in the die making through which these different and irregular wire sections were drawn—would use well constructed furnaces whose temperature was under perfect control when tempering or stiffening the single wires, the length of some of them running into miles. Knowing master and men who produce these particular German ropes, he felt that to produce such an article here would require something like a social revolution in the business management, the drawing office, and of the workshop staff.

In the American section the wonderful performance of some turning tools shown by the Bethlehem Company claimed his attention. Working himself seven automatic wheel cutting machines, which were always crowded with work, and whose capacity seemed to be limited only by the power of the cutters

to stand up to their work, he felt what a gain it would be to find a steel for the cutters which would allow of a double, nay a treble speed, as was shown to be the case with those particular turning tools shown. In company with Brown & Sharpe's representative, who was looking out for a similar conquest, he had the advantage of having the performance of that steel explained by the metallurgical engineer of the Company. At the Bethlehem works it was the rule to leave these tools in the machine for twenty minutes, give them as much work to do as the power of the lathe would allow and then take them out for grinding. Examining carefully, with a magnifying glass, a tool that had been working for twenty minutes, the cutting edges seemed hardly to have been blunted, but immediately behind the cutting edge there was a hollow dug or worn out by the curling up of the chips. Neither tool nor chips looked as if cutting action had been going on, but both looked as if the work had been done by ripping off the metal. The hollow in the tool seemed at times to be partly filled with parts of the curling chips, which themselves seem to take the thrust rather than the tool steel itself. Mr. Renold came to the conclusion that for milling cutters, where the conditions were such that the metal must be removed by a clean cutting action, this new preparation of steel had no advantage. The attendant of this exhibit admitted that the tool was only suitable for roughing out and not for finishing purposes.

It might interest some to know how the Bethlehem Company came to find out this process. Being extremely busy with work that had to be got out (no new machines were procurable, and if procurable there was no room to place them nor sufficient additional power to drive them), they had to speed up their machines all round. However, soon the point of endurance of their Mushet tool steel was reached, and then their Manager and one of their Metallurgists

were appointed to make experiments and find out how the endurance of their tools could be further increased. After two years of hard work, with all necessary machines, facilities, and a great deal of material for experimenting upon at their disposal, they at last succeeded in finding this wonderful preparation, by which two, three, and when used upon chilled rolls, four times as much work could be turned out than was possible before. What a Yankee way of overcoming obstacles! Questioning whether there were any difficulties raised by the workmen when required to run their machines so much faster, he was assured that this was not the case. He understood that this process could be applied to any tool steel. (Mr. Webb: Any self-hardening steel?) Well, he understood them to say it could be applied to *any* tool steel. The Bethlehem Company wish to give Shop licences for the use of their process, and with this view were at present in negotiation with some Sheffield firms.

In connection with these foreign exhibits and the competition they make in our home markets, he wished to draw attention to the very low freights at which steel could now be brought from Sweden, Germany and America to our Manchester Port. The very lowest rate to bring steel from Sheffield was 8/- per ton, but this applied only to the very crudest raw material, and 16/- was more the correct rate of the class of steel used in Manchester. Now from Sweden there were two steamers sailing weekly for Manchester, the one charging 7/- and the other 8/- per ton. Sweden therefore in a sense was nearer to us than Sheffield. German steel, which came some 300 miles from up the Rhine, was delivered weekly in the Manchester Docks at 20/- per ton, and twice a week *via* Grimsby at only a few shillings more. With a consumption of a few hundred tons a year these foreign sources of supply are well worth looking after, and the English workman, as well as his rolling mill

master, might well ponder over it before these inroads have made too great a progress.

Mr. C. Day, speaking with regard to the engine exhibits, said he thought a country which had been practically the pioneer of engine building, should not be represented by only two Corliss engines, and one or two other stationary engines, of comparatively large size. He was not speaking of small agricultural engines. There was not one of the old-established Corliss engine builders in this country represented at the Exhibition, so that no one could obtain from it any clue as to the state of Corliss and big stationary engine building in England. What English exhibits were at the Exhibition was to his mind, far below the best standard of English practice. One engine he noticed had certainly some excellent points about it—which, however, he thought were embodied in many Corliss engines in England— but the workmanship and ideas of beauty displayed in it were bad. As to the Exhibition generally a striking feature was the large proportion of horizontals, especially when they remembered that the engines were coupled with dynamos.

In England, engines or electricity stations, &c., were usually designed to occupy as little space as possible, but at the Exhibition it was surprising to find so many horizontal engines which took up so much more space than verticals, although certainly the biggest engines were verticals. The foreign engines he saw there he certainly considered better than the English engines as regards finish, and this did not seem to be an "Exhibition" finish, but a genuinely good appearance, attained at a small cost, and obtained to a large extent by good painting, and nice lines of design. The only engine which seemed to have an "Exhibition" finish was an English engine.

Another point he noticed in most of the foreign Corliss engines was the extreme quietness of the dash-pots. Foreign engineers studied this point of "noiselessness," and many of them used Colman's oil dash-pot, which worked excellently and very quietly. Then, again, the foreign firms took care to put a very good and well finished flooring round the engines, which was in marked contrast to the flooring round one of the English engines, consisting of strips of oil cloth of different patterns As to economy of working, one could not get much idea of this from an exhibition, but from certain figures he had obtained there, and which he had had confirmed in other quarters, the steam consumptions some of the foreign firms were prepared to guarantee were better than any English firm he knew were prepared to guarantee, and as far as he could gather these were generally fulfilled. In one respect, however, he thought foreign firms were behind this country, viz., in high speed engines. The Willan's engine shown at Paris was to his mind a better commercial engine than any other in the exhibition. It represented the maximum amount of power for space occupied, and, if manufactured on good commercial lines, per £ expended, and owing to the high speed, the cost of the dynamo was comparatively low.

It was interesting to note, in connection with the engines combined with dynamos shown at the exhibition, that the majority of the latter were alternating current machines, either one, two, or three phase, and there was a striking uniformity in the design of the different alternators, which differed only in minor points that did not affect the basis of the design. Some of the alternators were driven by single-crank, slow-speed engines. Few people in England, certainly few electrical engineers, would allow that plan to be adopted. It would be impossible, they would say, to run it in parallel with other alternators. The fact remained, however, that in the cases referred to

they did adopt this method, and managed to run in parallel. In some cases special devices were added to the alternations, such as an *amortisseur*.

In the case of any alternators in England which were run from single-crank engines, they were, so far as his experience went, something like high speed; the revolutions were always over 200. Generally speaking, he gathered that high-speed engines, which had achieved such success in England, had not, so far as was indicated by the exhibition, achieved the same success in France, and one wondered why this was the case, especially if they adopted alternating current machines, which could be designed for any speed they cared to go to, cheapening the dynamo proportionately. It was a striking thing that the Continental people should have settled down to slow-speed engines and alternators, and would seem to indicate that they considered the slow speed engine the better of the two.

As to the Bethlehem exhibit, if it enabled them to increase the work obtained from their tools by two or three times, it would save them from the necessity of extensions of works, and re-arrangements of existing establishments would be all that was necessary to enable them to enlarge their production.

In conclusion, he might add that the points we had to note from the Exhibition, so far as engine building was concerned, was that we should study appearance and finish more in our productions; and that, whilst in high-speed engines we were far ahead of Continental nations, in slow-speed engines they held the lead.

Mr. George Saxon said that, while we were behind in many things, in others it had been proved, many times, that we had only to waken up to resume the lead. As a matter of fact, many of the designs embodied in the foreign engines spoken about were English designs, the work of English draughtsmen,

and, if it were looked into closely, it would be found that foreigners had very little claim to many of the designs in their engines that were so much admired by us. As to the fact that we only occupied the fifth place in the size of our engine exhibit, it could be accounted for in one or two ways. They all knew of the peculiar national feeling that existed about the time of the preparations for the Exhibition, and probably the friction between ourselves and France caused some of our manufacturers to hang back from exhibiting.

Then, again, we had not the same encouragement from the Government that other foreign exhibitors enjoyed. He might, however, say that when a firm were exhibiting they ought to put down the best plant they could and pay special attention to the finish, so that it would be a plant worth showing. Some people thought that, when they sent work to an exhibition, they should send it just as they would sell it in the ordinary mercantile way. He differed from that view.

Now, in respect of this question of finish, he had greatly admired many of the foreign engines shown at the Exhibition, and the English exhibits suffered by comparison. English manufacturers did not seem to realise that they ought to go to special trouble and expense in preparing plant to be shown at an Exhibition, where it would be subject to so much criticism, and, consequently, should be made as good as it could possibly be made. Again, in one of the exhibits he noticed a large fly-wheel, that had been turned true in the lathe, but, when put on the shaft, wobbled terribly, and in a way that might have been avoided, and should have been avoided, particularly in an Exhibition. Then, again, some of the dashpots in English exhibits were knocking very badly, and this was a point that should have been remedied as far as possible. On the other hand, the foreign exhibits, on the whole, worked fairly noiselessly.

The lesson to be learned from the Exhibition was, that they must pay greater attention to design and finish in any future exhibits they might make. If they intended to exhibit at all, they ought to spend some time and trouble in making the exhibit as perfect as possible. They would then do themselves and their country credit, and gain some of the leeway they had lost in the past.

Mr. Joseph Nasmith observed that the lesson was not simply that they must give a better finish to engines sent to Exhibitions, but that generally in the making of engines or anything else they should give the closest attention to detail. The fact was that it was not in Exhibitions alone that German, French, and Swiss engines were more than holding their own against English competition on the Continent, but in engines actually put into mills or works for actual use, the attention to detail was much greater than in this country. He was not, however, so much impressed with the guarantees given by foreign engineers as Mr. Day, because in most cases they related to a steam trial which the maker himself conducted.

They would find extreme difficulty in getting any of the Continental engineers to undertake to put down an engine and guarantee a certain steam consumption, on a trial to be conducted by an independent authority, such as an insurance company. The engineer usually carried out the test himself, although he allowed the engineer of the firm buying the engine to be present, and exercise some sort of check. Making allowance, however, for all that kind of thing he might say that next to the late Mr. Peter Willans, there was probably no firm or person in existence that had done so much for steam engineering as the firm of Sulzer. They had introduced what English engineers had sneered at as refinements, but the general effect was seen in the fact that taking the engine all

round they could guarantee a lower steam consumption then the average of the best English engines.

There must, therefore, be some points in the construction of their engines, which it was desirable for us to learn and copy. The time had come when all our insular prejudice as to being ahead in the engineering trade ought to be dropped, and we ought not to consider it any more a disgrace to copy the best points of other people than they did to copy our best points. He was not, however, impressed by many of the engines he saw at Paris during his short stay, although they had certainly a beautiful finish. Even the famous Sulzer engine, judging from the exhibit, appeared to be one in which there was a great deal of waste space, and in which the gear could very conveniently have been lessened so far as the area it covered was concerned, and made much more direct and simple. In one engine (a comparatively small one) with the Proell gear, there seemed to him to be such a direct connection, and the valve gear was so much simplified in parts that he thought it a better example in this respect than the Sulzer engine. He was not going to say the Sulzer gear was not a good gear; results had proved the contrary, but at the same time he did not think they need run away with the idea that in order to get the required effect in this country they must of necessity accept the Sulzer gear—a recommendation partially given by Mr. Saxon in his paper.

This fault of "spiderliness" in the valve gear appeared to him to prevail to a very large extent in many of the large vertical engines shown at Paris. He had also noticed the Allis engine, made in France, but presumably on the Allis pattern. It was sold cheaply, and, in his judgment, made cheaply. The design was not by any means a pleasing one. The wrist-plate gear seemed to him to have the fault of spiderliness, and if that was the best thing the Americans could send over, and our engineers would take a little trouble, we had not much to fear

from that side of the Atlantic. Mr. Forth, in his paper, referred to the fact that the bent of the Continental mind, and more especially of the Continental engineering mind, was towards attention to detail.

The training of the students, and youth generally, was of a kind which tended to impress upon them the value of detail. To some extent they attended to that too much, but, despite the faults of their training, the fact that they were impregnated with the spirit of attention to the smallest details of a machine undoubtedly in the main tended to produce a better machine all round. In this country we were too apt to say "The thing will do," whereas the German, more especially, would say that nothing would do so long as one little detail could be improved. Unless we approached the problem of engine-building, or any other problem, in that spirit, the day of success for this country was gone, and the day of success for some other country was at hand.

Mr. Hans Renold said that during a visit to one of the works of the Sulzer Company he was struck by the extreme attention paid to details. There were just then some large horizontal engines being finished for an electrical installation in Moscow. For our tightly packed island such a type, and for such a purpose, might be out of place, but then Russia was not England. The care bestowed upon obtaining clean and pleasing curves and forms for all parts of the engine body was astonishing. Holding down bolt bosses were trimmed off with care, as if on their correctness a great deal depended. What a waste! he heard some of his Anglo-Saxon friends exclaim. But after all was it? Did not, the whole world over, a man more readily pay for something he was pleased with, especially when it was useful and good at the same time? And does not such a carefully finished engine not receive more attention by its attendant, and thereby last longer?

Mr. HARTLEY said that if English engineers intended to compete with American and Continental firms they would have to test their engines far more carefully and efficiently than they were in the habit of doing, and also they would have to use the best and most reliable instruments for that purpose.

A few weeks ago he had received an order from a firm of Continental engineers for eight Tabor steam engine indicators with electrical attachments. These were for testing four cylinder triple expansion engines, and the object in getting these indicators was to put one at each end of each cylinder, so that all the diagrams would be taken simultaneously.

The rule of thumb method adopted as to the ratio of cylinders one to the other in multi-cylinder engines in this country by some makers and the want of uniformity in the proportion of cylinders also required attention. One firm made the ratio of high-pressure cylinder to low-pressure cylinder as 6 to 1, others 6½ to 1, others 7 to 1, for the same boiler pressure. They could not all be right, and the probability was that none of them were right.

If instead of setting one man to take diagrams (often with an old and antiquated instrument, and this man had four cylinders to indicate, make eight shifts on his indicator to make the eight diagrams required, and the probability was that the load had varied during the operation by 10% or even 20%) they were all taken simultaneously they would get the exact load the engine was driving, and could then design their engines and proportion their cylinders accordingly, getting the best possible results instead of making allowances for variations of load and increasing the cylinder capacities to allow for this which made the engines too large for the load they had to drive, and consequently wasteful. They would find that it would pay them handsomely to pay attention to these matters, and by so doing

they would get a degree of economy which was not at present obtained.

With regard to guarantees he knew positively of cases where independent tests had confirmed in every detail the results the makers had obtained in their own tests.

What engineering firm here would undertake to put down a compound engine to drive a cotton mill with 160lbs. boiler pressure, and give a guarantee that only 12·9lbs. of steam per HP per hour would be consumed. This had already been done by foreign firms and the guarantee fulfilled, and the engine found to be doing this same duty after twelve months working.

Mr. Hartley then proceeded to what he had seen during a recent visit to America where he had been struck with the labour saving methods and appliances that were adopted to cheapen production. The saving in foundries by adopting pneumatic moulding machines was from 30% to 60% in the cost of production, and the output was increased from 40% to 55%. This was done in both brass and iron foundries, where previous to the adoption of these machines the best system of plate moulding by hand was in operation.

In conclusion, he was quite sure that we in this country could do work as well, and turn it out as cheaply, as any other country, but we must do it in the same way they did it, viz:—by reducing the labour cost, and to do this labour saving tools must be adopted both in the foundry and the machine shop, and we had at the present time an opportunity of purchasing the very same labour saving tools here and putting them in our works, as were used by both American and Continental firms.

At one works it was proved to him that the whole labour cost in making a 1in. brass wheel valve was but 2d., other sizes in proportion.

How much more do these cost here?

Mr. Lawson questioned whether valves could be produced at the cost named, but Mr. Hartley said the statement could be confidently depended on.

Mr. Phillip Robson said that almost all the engines in the exhibition made by Continental firms had inter-receivers, and that was an important point, as, whether they served as separators, so as to get dry steam into the second cylinder, or as radiators, they contributed very much to the efficiency of the engine. As to the design of engines, they should never lose sight of the principle of simplicity, which meant success, and ought to aim, in the first place, at getting efficiency by means of simplicity. It had struck him lately, with regard to the manufacture of engines for large units, that the stationary engineers might very shortly have to look for competition much nearer home than they had thought of looking. During a recent visit to the North of England he found several first-class marine firms were taking up the manufacture of these large units.

A great deal had been said of attention to detail, and he might say, from experience, that marine engineers were not wanting in that respect. Take, for instance, the case of a 30-knot destroyer, and what did they find? They got 6,000 horse-power on a total weight of machinery—engines, boilers, shafting, water in boilers, and condenser—of 150 tons; that result was not attained without the greatest attention to detail. They adopted refinements which the ordinary land engineer would scarcely dream of unless he had seen them; and they could go to the leading draughtsman in the office of one of these firms, and point to any detail of an engine, and he would be able to give the working stress of it so far as it was calculable. He fancied that if the same spirit was transferred into the manufacture of stationary engines they would have to look for keen competition from the marine engineers.

Reverting to the exhibition, Mr. Robson observed that special interest attached to some high-speed pumps coupled to electric motors. These included reciprocating pumps, capable of being worked up to 300 revolutions against head pressures equal to at least 300lbs., and this was effected chiefly by the introduction of special control valves. In these pumps they had a remarkable illustration of the value of the combination of the work of scientific and practical men, which had been brought fully into play in the researches which led to the invention of the valves referred to.

Passing on to the subject of technical education, Mr. Robson observed that Manchester, at least, was rising to a sense of its responsibility in this matter, and there would shortly be opened a large school, belonging to the municipality, in which very important work was to be carried on. The dry bones of theoretical investigation were to be quickened into new life by experimental research extending over the whole field of engineering, and the engineering department was to be presided over by one of their fellow-members. The association might do worse than become militant supporters of, and sympathisers with, the work of that institution.

With regard to our position relative to that of our foreign competitors, it was true that we had something to face; but he trusted we had the capacity to meet it, and if those whose life to a great extent lay before them only remembered the inspiring records of the past history of English engineering, and kept a high ideal in view, he had confidence they would strive, not unsuccessfully, to maintain the honour and prosperity of the country untarnished and undiminished.

THE DISCUSSION WAS ADJOURNED.

ADJOURNED DISCUSSION,

SATURDAY, DECEMBER 8TH, 1900.

Mr. J. VOSE said with regard to machine tools it appeared to him that the Continental engineers had pretty well grasped the leading lines of construction, and could provide tools to answer their purpose. The lesson for us was that any tools we sent over there must have something special about them, and he thought there was a market for tools that had some really good substantial points. Another thing he was greatly interested in was the workshop educational scheme of the Brown & Sharpe Co. There was first a period of probation, and then the young men started on wages which compared very favourably with the wages in England. The apprentice was kept at one class of work until he was master of it, and so on until he had completed his course. Provision was also made for training in the theoretical branches. The system had very good results, which redounded to the advantage of the firm, and they could get an idea of the class of men they had at their service from the young men they saw at the firm's stands, who were able to speak with authority about every machine and also able to work them. By the firm's system youths with no great social advantages were not debarred from the advantages of apprenticeship, as they could act as "operators" with no training rights and then when the time came become apprentices.

He thought we in this country had something to learn from that scheme, as the apprenticeship question was in rather an indefinite state, and the firm mentioned had shown an example by doing something definite in the matter.

Mr. JAMES SAXON said the stationary engine exhibit at Paris was a very fine one, and taking the exhibition as a whole it was

one such as they were not likely to see again for many years to come. One noticeable thing which appealed to all of them was the splendid display of large vertical engines, particularly those of Germany. He thought they might take it for granted that vertical engines had come to stay, especially in connection with the development of electrical power, and where economy of space was necessary. After all, however, horizontals seemed to be most in favour amongst the manufacturers who exhibited, and he thought they would continue to be the most popular amongst those who wanted stability and accessibility of parts, and particularly where they were not stinted for space. There was no example of the mill engine at the Exhibition. In fact there was not an engine there which had a main driving belt or ropes, everything being apparently given up to the electrical transmission of power.

He had also been struck with the backwardness in regard to engine building of those who promoted the exhibition, namely, the French, but perhaps they would reap a reward from the Exhibition through having seen what others had done, and be stimulated thereby. We ourselves did not hold a place in the Exhibition which we could look upon with pride or satisfaction. Although well represented in many respects still he felt that the exhibits did not do us justice. Probably the fact that we did not receive the same encouragement from our Government as was given in other countries had something to do with this, but certainly considering that we were the greatest exporting nation in tools, engines, &c., one would have expected to see a greater British exhibit in that department than there was. A foreign exhibitor, with whom he had had an opportunity of speaking, told him that they could not take the British exhibit as representing Great Britain's position because some of their best firms must have been too busy to send exhibits. He further said that one fault with the English was that they still adhered to

the Corliss gear, and if they would only take up the Colman or Sulzer valve they would beat Continental engineers entirely.

Personally he thought some of the Continental engineers were behind with respect to governors. As to lubrication, English engineers might take a lesson from the foreign exhibits. In fact some people might think the thing had been overdone, but there was certainly something in that direction which was worth copying. Then there were the crank splash guards, which were almost universal in the Continental engines, and which might be adopted by ourselves to a greater extent than they were. He did not know whether Continental engineers got more money for their engines, but they certainly seemed to be more lavish in the details and the multiplication of etceteras which of necessity added to the cost.

The arrangement of the levers and valve handles, so that the mechanism could be worked from a central part, was also a point to which particular attention was given. As to the design of the engines generally he thought with regard to the main lines they were very little different from our own, although some were lighter and some heavier in build. On the whole we had no need to fear foreign competition unless it might be on the question as to whether we had the best kind of valve. If English engineers were satisfied that the Colman or Sulzer type of valve was the best, the sooner they adopted it the better. They might, however, think they could do better with the Corliss. In any case it seemed that that was the only point in which they might possibly, with advantage, copy Continental engineers.

In connection with the English exhibits there was one point he had almost forgotten to mention, viz.: the engine by Messrs. Galloway, in which they had introduced the principle of adopting the throttle valve in addition to the cut-off. It appeared to have been shown that, under light loads at any rate, the throttle

valve was not only more economical but resulted in a more uniform turning effort, but on medium and heavy loads the ordinary cut-off of the Corliss valves ought to be used. That at any rate was the idea of the combined arrangement, which was not adopted on any other engine in the Exhibition.

Mr. E. G. CONSTANTINE said he had been told by one or two marine engineering friends, who had examined the marine engine exhibits, particularly that of the Creusot Co., that the bolts and the caps for the bottom ends were forged solid and afterwards turned. If that was a specimen of their work it was scarcely necessary for him to offer any comment upon it. He was also told that there appeared to be a good deal of complication about the engines, and an apparent effort to destroy the simplicity, which older fashioned marine engineers were fond of thinking was necessary in engines used on board ship.

Mr. J. MITTON said he was glad to hear Mr. Saxon refer to the Galloway engines. The origin of the combination referred to was a desire to make the governing of electric lighting plant with a Corliss engine reliable when the whole of the load was taken off. The throttle was so designed as to be brought into operation at about $\frac{1}{10}$th of the cut-off, so that the engine had all the virtues of an automatic engine from its whole power as low as $\frac{1}{10}$th of the cut-off in the high pressure cylinder. Beyond that point the equilibrium valve was brought into play, and the governing was not materially affected, the governor being designed accordingly. By this means they could work the throttle valve at light loads, and have all the advantages of automatic governing for heavier loads. That combination was not adopted in any other engine in the Exhibition.

The same engine had the advantage of forced lubrication throughout, and he did not think any other engine of the same

class had it. He thought it should really be known that we were not so far behind in the mechanical and essential principles of engineering, although not so gaudy in outward appearance.

Mr. A. L. Mellanby said that he had not intended to speak that evening, but the remarks of the two last speakers upon the question of governing and of marine engines had brought him to his feet.

It was remarkable and also lamentable that, at the present day, engineers should still cling to the opinion that governing by expansion was so much more economical than governing by throttling. The results of so many engine trials had been published disproving this idea that it almost seemed as if the papers read before the various scientific societies were entirely neglected by engine builders, for whose benefit they were chiefly written.

With regard to our position in the building of marine engines he thought that, as yet, we had little to fear from our Continental competitors. They could not touch us for price or delivery, and the British engineer had not learned much from the Paris Exhibition about the building of marine engines. He also felt sure that the marine engine shops on the North-East Coast could manufacture large steam engines, now so much used for generating electricity, equal, in every respect, to any shown in the Paris Exhibition. Mr. Saxon had stated that we were behind our foreign competitors in matters of detail, but that was far from being the case with our marine engineers. Most careful attention was paid by them to the minutest details and beauty of design was looked for in the work of every good marine draughtsman. He considered that the vertical engines shown in the exhibition and spoken of with so much awe by some members, although extremely well finished in every respect, were not to be compared for graceful appearance with

the engines turned out every week by our Clyde and North-East Coast marine engine shops. Now that marine engineers were energetically taking up the manufacture of stationary engines, he considered that the Lancashire engineers would find them to be rivals much more dangerous than any of their Continental friends.

It was rather amusing to hear several of the members refer to the drop valves so much used on the Continent as if they were entirely unknown in England. Two very well known English firms, Messrs. Robey of Lincoln and Marshall & Sons of Gainsborough, had long used this type of valve. Messrs. Robey had kindly informed him that they had patented the trip gear used with their drop valves 13 years ago, and were now turning out engines fitted with it whose indicated HP amounted to from 12,000 to 15,000 per annum.

It had been mentioned that we were behindhand in our technical education, but if any firm was without several officials of high scientific knowledge it was entirely their own fault. At the present time there were many men who had taken the engineering courses at University Colleges, and who were compelled to accept posts in second rate technical schools because they could not obtain a living wage in any engineering establishment. He was not thinking of boys who had gone straight from school to college without having any practical engineering experience, but of men who had served their apprenticeship and devoted several years of their life to obtain the scientific knowledge they felt was necessary to them. He knew cases where men of the type just mentioned had been in fairly good positions before they went to college, but after receiving their training found that employers looked askance at them, and preferred what they called a sound practical man. But whatever might be said upon that point, he was convinced that the products of our British engineering colleges were the equals of those turned

out by the Continental and American schools. If therefore the asserted superiority of these people in the engineering line was due, as so often stated, to their technically educated men, he hoped the engine builders of this country would take it to heart and give employment to some of our own young educated engineers who were so eager to obtain situations.

Although perhaps our national system of education could not be compared with the elaborate and somewhat cast-iron schemes adopted by other countries, he had not yet found any foreign institutions that could compare, for purposes of real education, with our great public schools. He was proud to think that the heads of these institutions did not look upon education simply as a means to enable their boys in later life to obtain something to eat, but that they endeavoured to train them so that they would become the cultured men and gentlemen for which our land was so justly noted.

Mr. Joseph Nasmith referred to the splendid educational exhibits at Paris, and reminded the members that through the action of the Chairman of the Technical Instruction Committee of the Manchester Corporation the American educational exhibit was coming to Manchester, where it would be on view early in the new year. Anyone who wanted to know how the Americans graded their systems of education would do well to go and see this exhibit when it arrived. One lesson we had to learn, more particularly from the Americans, was that however important it might be to design and manufacture, it was equally important to know how to sell.

He could bear out what had been said about the Brown & Sharpe Co., and had been struck with the fact that this tool exhibit was in the hands of young men. Engineers in this country would have been terrified if they had been asked to allow their exhibits to be in the hands of young men in that

way. The Americans were, however, recognising that a well trained young man with a career to make was the best representative for purposes of selling. He would advertise their tools in and out of season, and gradually persuade other people that what he said was true. There was one point that had not been referred to in their discussions, viz., the gas engine exhibits. He hoped they would be able sooner or later to get some information which would enable them to appraise the value of the gas engine for large powers.

Mr. O. M. Row said a good many of the British exhibitors had not sufficiently studied appearance in their exhibits. When they were going to exhibit they should put the best appearance possible on their goods. If they as engineers would tack on a little art to their science and ability to build a good thing, they would do better. As to the Creusot exhibit, it was one of those engines for a warship, which had to be kept as small as possible, and that perhaps gave it a complicated appearance, but apart from that it was a really good piece of work from beginning to end, and there nothing better in the products of the North of England or Scotch shipbuilding yards. The lesson we had to learn was the necessity of wakening up, and recognising the seriousness of the situation, if we did not wish to lose our trade.

The PRESIDENT said both his partner and himself had visited the Exhibition, and they had also sent five of their leading men there. His feeling was that we had a great deal to learn. Our exhibit was very poor and small in the metallurgical and mechanical lines, and would give many people who visited it the impression that England was played out. As to the quality of our exhibits there was nothing to boast of beyond the locomotives and textile machinery. Even in locomotives the

advantage was more apparent than real. The English locomotives were exceedingly well finished, but if they had to do Continental work he fancied they would have to be designed differently from what was customary here. One point which gave the English locomotives a good appearance was the fact that all the valve gear was inside, whereas in the foreign locomotives it was exclusively outside. They must not, however, overlook the question of accessibility, and they had to admit that the outside gear was the easiest to get at. To his mind the Walschaert valve gear was better than the ordinary link motion, and this gear, as they knew, prevailed in some, if not all of its modified forms on the Continent.

So far as textile machinery was concerned, it was the best part of the show as regards English exhibitors. In machine tools, with two or three exceptions, in which American ideas had been adopted, there was no novelty whatever in the English exhibits; in fact some of the things shown were what they had been accustomed to ever since they were boys. As to the engines, referring to the Galloway exhibit, he might mention that between twenty and thirty years back he had tried to make a cut-off and throttle valve go together, and failed, and he believed a similar fate would befall anyone else who attempted to do it. There should be no difficulty in arranging a Corliss gear that would control an engine when the whole of the load was thrown off. No engine would run away if no steam were admitted, and if Corliss gear could not be arranged for that he pitied the designer.

Comparing the Creusot and the Vickers-Maxim exhibits, he thought careful examination would show that we were not at the front even there; at any rate looking at the exhibits from the outside. One point that struck him in the foreign engines was the evidence they afforded of attention to detail. In this we came exceedingly short. For finish and careful and propor-

tionate design he thought the engine shown by Carril's, of Ghent, was the best in the whole Exhibition. As to valves we could not claim the origin of the Corliss, or of the drop valve as arranged by Corliss or Sulzer. The drop valve was only a resuscitation of the old stamper valve, used many years ago in the Cornish pumping engine. This went out of use here with the increase of pressure, and it was interesting to note that in the shape of the Colman and Sulzer valves the drop valve was being used at high pressures. Anyhow the drop valve was a right down good type, and he liked it better than the Corliss; the only point was to persuade customers to have it. He believed that in this country the customer was often more to blame than the engineer, because he would not pay the proper price, and looked more for the bottom estimate than for the system that would work most economically. It had been left to Germany to find out the means of welding by chemical action. As to the Bethlehem process for increasing the speed of tools, although the Americans had been the first in the field with that process, still something had been done in this country in the same direction, and in his firm's works they had been using a steel which enabled them to run the tool at a considerably increased speed. As to the training of young engineers, we in this country were a long way behind the Continent and America. He hoped the Technical Schools in this city would be of very great service in helping on the education of the young engineer. In the summer of the current year he had visited an engineering works at Augsburg where they had a very good system of educating apprentices, both theoretically and practically, in such a way as to bring out the best faculties of the lads and young men connected with the establishment.

With respect to marine engines the Creusot engines appeared complicated through exigencies of space, but after all they were

a right down good job. There were two other sets of marine engines, of French make, which although not very highly finished, appeared to be good and useful types. The only "electro plated" engine he saw in the Exhibition was an English one. As to the Diesel engine, they might not all be aware that it was being made in this country at the present moment, and he was responsible for the making af it. He hoped before long to give more information with regard to it, and possibly show it to the members. They hoped to make it much simplier than it was at present. It had been tested by the most eminent German professors, who found the consumption to be about one-half that of the best oil engines at present running. A Company was being formed for making the engine in this country and he was taking a prominent part in it. In concluding his remarks he would remind them that we were in danger of letting the work of the world go past us. The show at Paris certainly did not impress a foreigner with the idea that we were in the front rank in engineering, and unless we looked to it we would ultimately be accounted not first, but a long way behind.

Mr. A. Saxon remarked that the time-limit of the discussion had now been reached, but they must not think that if time had permitted he would have allowed some of the remarks that had been made to go unchallenged.

45TH Annual Report

OF THE COUNCIL,

1900.

MANCHESTER:
HERALD & WALKER, POOL FOLD CHAMBERS, OFF CHAPEL WALKS.
1901.

OFFICERS.

1901.

President:

MR. HENRY HODGSON.

Vice-President:

MR. HENRY WEBB.

Treasurer:

MR. JAMES WALTHEW.

Trustees:

MR. G. CARTER
" J. WEST
MR. T. ASHBURY
" S. DIXON
SIR W. H. BAILEY.

Managing Committee:

MR. W. TAYLOR,
" C. DAY
" H. HALLIWELL
MR. J. SAXON
" W. SMITH
" J. E. HARDMAN

Librarian:

MR. R. GASS,
19, City Road, Higher Openshaw.

Secretary:

Mr. FRANK HAZELTON,
100, Ayres Road, Brooks' Bar, Manchester.

Annual Report of Council,

1900.

The Council have pleasure in presenting the 45th Annual Report of Proceedings.

To the membership roll during the year have been added—

17 Honorary Members.
18 Ordinary Members.

Total 35

and after taking into account the loss by death, resignation, and erasure, the total number of names of all classes on the roll amounts to 470, as against 453 in the previous year, namely:—

27 Honorary Life Members,
176 Honorary Members.
267 Ordinary Members.

Total 470

Upon reference to the Financial Statement, as certified by the auditors (see pages 367-8), it will be seen that the balance standing to the credit of the Association, after payment of all accounts due up to the 31st December, amounts to £4,790. 12s. 8d., as against £4,488. 5s. 7d., at the close of the preceding year, thus showing a surplus of £302. 7s. 1d. on the year's working.

Superannuation Fund.—At the commencement of the year there were seven superannuants and subsequently another was added, but owing to one decease the number presently remains the same, who are receiving a weekly allowance of 8/-

It is with regret the Council have to record that during the year death has removed the following members, brief memoirs of whom are appended on pages 361-6 :—

Birch, A. - - - -	Hyde.
Craven, John - - -	Manchester.
Daniels, Thomas - -	Patricroft.
Hill, W. R. - - -	Stalybridge.
Hilditch, T. - - -	Manchester.
Taylor, John - - -	Do.

The following gentlemen have resigned their membership during the year.

Atherton, J. J. - - -	Warrington.
Fletcher, J. A. - - -	Ashton-under-Lyne.
Beeley, T. C. - - -	Hyde.
Lee, S. E. - - -	Limerick.
McGregor, D. C. - -	Manchester.
Settle, T. - - - -	Do.

The following gentlemen have ceased to be members during the year.

Brown, A. G. - - -	Manchester.
Hargreaves, J. - - -	Rawtenstall.
Hewitt, T. - - -	Prescot.
Lefevre, E. - - -	Manchester.
Wintour, F. - - -	Do.
Whyatt, L. - - -	Do.

During the year, in addition to the ordinary meetings, the following Excursions and Social Gatherings have taken place, brief accounts of which are included herewith :—

Jan. 27.—44th Anniversary Dinner. Attendance 191.

April 28.—Visit to Wigan: inspection of the Chisnall Collieries of the Pearson & Knowles Coal & Iron Co. Attendance 50.

June 23.—Visit to Blackburn: inspection of the Works of Messrs. Yates & Thom, Blackburn. Attendance 130.

July 23.—Visit to Liverpool: inspection of the R.M.S.S. "Oceanic." Attendance 250.

Oct. 13.—Visit to the Gorton Foundry, of Messrs. Beyer, Peacock & Co., Limited, subsequently meeting at the Grand Hotel. Attendance 200.

Papers Read and Discussions held during the Year.

Jan. 13.—"**Inaugural Address**" by the President, Mr. Henry Hodgson, "**Our position as Engineers.**"

Feb. 10.—"**The Future Development of the Steam Engine,**" by Mr. Alfred Saxon.

,, 24.—"**Health in the Workshop,**" by Mr. J. D. Sutcliffe.

Mar. 10.—"**Topical Questions**":—1, Has steel used in the toolholder any advantage over a solid forged tool? 2, Is anything known of the relative merits of the various kinds of belts? 3, What is the best method of testing lathes for accuracy?

,, 24.—"**The Tool Room: for the Manufacturer, for the Engineer,**" by Mr. Walter Heap.

Oct. 13.—"**Paris Exhibition: its Lessons and Suggestions for Engineers.**" Discussion,

,, 27.—"**Flywheels,**" by Mr. A. Sharp, London.

Nov. 3.—"**Paris Exhibition.**" Adjourned Discussion.

,, 10.—"**Testing the Magnetic Qualities of Iron,**" by Mr. G. James Wells, Manchester.

,, 24.—"**Relative Merits of Triple and Quadruple Expansion Engines,**" by Mr. A. L. Mellanby.

Dec. 8.—"**Paris Exhibition.**" Adjourned Discussion.

The Council, in conclusion, desire again to express their cordial thanks to those members and friends, who have read papers or contributed to the discussions during the year.

ANNIVERSARY DINNER.

The Forty-fourth Anniversary Dinner of the Manchester Association of Engineers was held at the Grand Hotel, Aytoun Street, City, on Saturday evening, the 27th January, and was largely attended. Mr. Henry Hodgson, the President, was in the chair, and amongst others present were the Lord Mayor, (Councillor Thomas Briggs), Mr. F. Cawley, M.P., Mr. John West, Colonel Bridgford, Mr. Henry Webb, Mr. Samuel Dixon, Mr. John Craven, Mr. James Saxon, Captain Brooks, Mr. Joseph Nasmith, Mr. Thomas Ashbury, and others. Mr. W. J. Galloway, M.P., wrote apologising for being unable to attend, and Sir Andrew Noble wired "Obliged to leave England for Rome to-day on important business. Greatly regret, therefore, unable to attend dinner."

The loyal toasts having been proposed from the chair.

Mr. John West submitted "The Army, Navy, and Reserve Forces." These Forces, he said, were never more important than they were to-day. The were fighting a great war in South Africa, and he thought those present would agree with him that they were doing their very best under difficult circumstances. (Applause.) We were proud of their bravery, which showed that the British blood of old still ran in their veins, and we wished them God speed and good luck.—(Applause.) He was a man of peace, but one who saw how important it was to be well prepared for war.—(Applause.) We were now learning a severe lesson, and one which he hoped would be profitable in the future.—(Applause.)

Colonel Bridgford, who responded, said he had been connected with the Volunteer force for upwards of 41 years. Long ago this body of men was looked upon coldly, not only by

the professional soldier, but by the public. But the Volunteers had proved in a time of trouble that they were made of good stuff.—(Applause.) They had been looking forward to a time like that through which we were now passing, in the hope that they would be able to show their devotion to the country. He was very pleased to think that a contingent from his own battalion should be the first Volunteers from Manchester to go to the war. He was not going himself he supposed, because the War Office thought him too old, or perhaps otherwise unfitted, but he had a son who was at Ladysmith.—(Cheers.) We all hoped that place would before very long be relieved. (Hear, hear.) The abandonment of Spion Kop was to be regretted, but there was no cause for despair. It would be perfectly ridiculous to think that we could go into this or any other war and have everything our own way.—(Hear, hear.) The war we were engaged in had been forced upon us, and was a just war. With the means at our disposal, backed by determination, we should come out of it all right.—(Applause.) It would be well to reserve our criticism of the War Office, Her Majesty's Minister's and the Generals until the whole thing was over. Then a thorough inquiry could be made into the matter. (Applause.) He must say, however, that sometimes the War Office took a week to answer a question which one would think should not take ten minutes, and the Mounted Infantry had seemed to be sat upon from the very beginning of the war. We now saw the value of these men. All the faults, if faults there were, would however come out some day, and the blame could be laid on the proper shoulders at the right time. (Applause.)

Mr. Henry Webb proposed "The Houses of Parliament" in a humorous speech.

Mr. F. Cawley, M.P., responded. There was a feature in the Commons, he said, which he did not like. He thought the

Government was becoming more beaurocratic, and that the private member was becoming less and less important as an individual. This might, perhaps, be due to the strict party lines on which they were working. At any rate a private member had very little opportunity of bringing any measure before the House, and certainly had very little chance of ever passing one into law. Government measures, of course, had precedence of everything, but there seemed a tendency for the Government to take more and more time, and to allow private members less and less. He did not think that this was to the advantage of the nation at large.

Mr. James Saxon submitted the toast "Municipal Institutions." The municipal institutions of England, he said, were the envy of other countries, but there was a tendency, which he did not like, to interfere unduly with enterprises which placed them in competition with private traders.

The Lord Mayor, in reply, referred to the progress made by the Manchester Corporation in its various departments. One of the most striking advances has been made in technical education. The new Technical School would not be ready before next year, as the strike in the building trade had caused a delay of at least six months. The total cost would be a quarter of a million sterling, £200,000 of building and equipment, and £50,000 for the land. The engineering arrangements alone would cost £20,000. He believed, however, that it would turn out a very profitable investment for the City. At the present time there were 4,300 students attending the Technical School, and 1,200 the School of Art. Of these, 450 were thirty years of age and upwards, and 2,000 were upwards of twenty-one years of age. The engineering students formed the most numerous class.—(Hear, hear.)

Mr. SAMUEL DIXON proposed the prosperity of the "Engineering and Allied Trades." There were croakers to be found, he said, but whatever might be said to the contrary, the engineers were passing through one of the best periods they had ever enjoyed in this district. He would not ask for increased prosperity—that would be selfish—but only for a continuance of the present state of trade. Some people said that British engineering was played out. He did not take that pessimistic view, for the engineers were men of resource, and only wanted to know their difficulties to surmount them. He was sanguine that they had a bright future before them. Two years ago they passed through a great struggle, and since then they had been working under new conditions of management. These had, he thought, worked out well, and this was in a great measure due to the insistence of the late Colonel Dyer that everything the masters did in the final settlement should be done in the most equitable manner. When the history of that period came to be written no one would be found to have been a greater friend to the working man than Colonel Dyer.—(Applause.)

The PRESIDENT, in responding, said he thought the records of the Manchester Association of Engineers justified its existence for the last 44 years. The total membership was 453, the net gain on the past year having been 37. Their funds amounted to £4,488. 5s. 7d.; the gain on the year's working having been £263. 18s. 4d.—(Applause.) The Association was particularly valuable as it provided a kind of Education for the Engineers which could not be obtained elsewhere. With regard to the City's New Technical School he believed the internal arrangements were excellent. He hoped that whatever the Corporation spent on the outside of the buildings they would spend more on the inside. They should take care to have the very best and

latest appliances and also to see that none but first-rate teachers were engaged.—(Hear, hear.) Better workmen were made in the workshops than in the technical schools, but what he should like to see was young men attending the schools after serving their apprenticeship, and employers giving them facilities and encouragement to do so. He thought we should then be able to hold our own against anything which we might have to meet.—(Applause.)

Mr. JOHN CRAVEN also responded, and referred to the world-wide name which had been made by Manchester engineers. The past, he thought, showed us that we need not be afraid of the future.—(Applause.)

The proceedings closed with the singing of the National Anthem.

OPENING MEETING OF DISCUSSION SESSION.

VISIT TO MESSRS. BEYER, PEACOCK & CO.

The Opening Meeting of the Forty-fifth Discussion Session took place on Saturday, the 13th October.

In the afternoon about 200 members visited and inspected, by the courtesy of Messrs. Beyer, Peacock & Co., the Gorton Foundry, through which they were conducted by the General Manager, Mr. G. P. Dawson, and Principal Foremen.

Subsequently the party proceeded to the Grand Hotel, where tea was served.

After tea the evening was given up to the discussion, "The Paris Exhibition: Its Lessons and Suggestions for Engineers." The subject was divided into the following sections, namely:—Metallurgy, Stationary Engines, Machine Tools, and Textile Machinery; preliminary papers upon which were read respec-

tively by Messrs. H. Webb, A. Saxon, S. Dixon (per Mr. Ashbury), and J. Nasmith.

The discussion was adjourned till the 3rd November.

The proceedings were concluded by a cordial vote of thanks being passed to Messrs. Beyer Peacock Co. for the acceptable privilege granted to the members during the afternoon.

LIBRARY.

The following new books have been purchased and added to the Library:—

Management of small Engineering Workshops. Baker.
Polyphase Electric Currents and Alternate Current Motors. Thompson.
Electric Railways and Tramways. Dawson.
Electric Generators. Marshall & Hobart.
Paris Exhibition, 1900.
High Speed Steam Engines. Norris & Morgan.
Hydraulic Power Engineering. Marks.
English and American Lathes. Horner.
Management of Dynamos. Patterson.
Application of Electric Motors to Machine Driving. Stewart.
Hydraulic Rams. Clarke.
The Cycles of Gas and Oil Engines. Roots.
Modern Foundry Practice. Sharp.
Pattern-making. Horner.
Power Transmitted by Electricity. Atkinson.
Lubrication and Lubricants. Archbutt & Deeley.
Galvanized Iron. Davies.
Motor Vehicles and Motors. Beaumont.
The Internal Wiring of Buildings. Leaf.
Steam Engine Theory and Practice. Ripper.
Steam Boiler Heat Efficiency. Bryan Donkin.
Pumping Machinery. Davey.
Steam. Ripper.
Compressed Air. Richards.
American Foundry Practice. West.
Chemistry of Engineering Materials.

Engine Tests. G. H. Bairns.

Structural Iron and Steel. W. M. Twelvertrees.

Construction of Large Induction Coils. Hare.

The Association exchanges Transactions with the following:—

American Institute of Mining Engineers.
,, Society of Mechanical Engineers.
Canadian Society of Civil Engineers.
Engine, Boiler, and Employers Liability Insurance Company.
Franklin Institute, America.
Gas Institute, Incorporated.
Institution of Civil Engineers of England.
,, Engineers and Shipbuilders in Scotland.
,, Mechanical Engineers.
Iron and Steel Institute.
Liverpool Engineering Society.
Manchester Geological Society.
,, Literary and Philosophical Society.
Midland Institute of Mining, Civil and Mechanical Engineers.
Mining Association and Institute of Cornwall.
Mining Institute of Scotland.
North of England Institute of Mining and Mechanical Engineers.
North-East Coast of Engineers and Shipbuilders.
South Wales Institute of Engineers.
Society of Engineers.

The following Publications are received periodically:—

Cassier's Magazine.
Colliery Guardian.
Fielden's Magazine.
Engineer.
Engineering.
Iron and Steel Trades' Review.
Marine Engineer.
Mechanical World.
Practical Engineer.
Textile Mercury.
,, Recorder.
,, Manufacturer.

REPORTS OF EXCURSIONS.

VISIT TO CHISNALL COLLIERIES, WIGAN.

The first of a series of Excursions arranged by the Association took place on Saturday, the 28th April, when upwards of fifty members visited the new Chisnall Collieries that are being opened out at Coppull, near Wigan, by the Pearson & Knowles Coal and Iron Company, Limited.

The party, who travelled from Manchester to Wigan by rail, were met at the Victoria Station, Wigan, by Mr. John Knowles, General Manager of the Collieries, and conveyed in carriages to Coppull. The afternoon was spent very interestingly in a thorough inspection of both the surface and underground works, every facility for which had been provided by the Company. Before proceeding on the round of inspection, Mr. John Knowles, after expressing regret that Mr. Brancker the managing director of the Company was unable to be present, said the collieries were not yet in a completed condition, but the members would nevertheless have an opportunity of inspecting the modern system on which mining was now conducted. When they started sinking they had to encounter unexpectedly some 50,000 gallons of water per hour. This, however, had been successfully dealt with, and they were now opening out two shafts which when finished would have a capacity of raising 3,500 tons of coal per day. One of these shafts was already sunk to the Arley mine 470 yards below the surface, and the other shaft, in which sinking operations were still in progress, had been sunk to a depth of 160 yards. The general plant on the surface consisted at No. 1 pit of a pair of winding engines 36in. by 72in. with Cornish valves, supplied with automatic cut-off gear, steam reversing gear, automatic steam brake, and also a steel built drum 20ft. diameter and 8ft. wide, made by their own Company at the Dallam Engineering Works, Warrington. There was also a Walker Bros. patent ventilating fan 22ft. diameter by 8ft. wide, driven by rope pulleys 16ft. by 8ft., with ten ropes, and having a capacity of 300,000 cubic feet of air per minute, and a water gauge of 4in. This was driven by twin compound fan engines fitted with 19in. high and 32in. low pressure cylinders, 3ft. 6in. stroke, both fitted with improved cut-off gear and condenser, and each engine could work high pressure if required, The head gear at No. 1 pit was 70ft. from the rail level to the centre of the pulley, which was 18ft. diameter. Ormrod's patent detaching hooks were provided, and there were extra appliances in the receiving rods, in the event of the

detaching hook failing, to prevent the cage going down the shaft. At No. 2 pit there was a pair of winding engines, 30in. by 60in., with Eatock's slide valve and steam brake drums 18ft. diameter for King coal, and 12ft. for Chisnall seams, and 9ft. wide, made by Wood & Gee, Wigan. There was a pair of quadruple ram pumps with four 6in. rams, 10in. cylinders, and 15in. stroke. The boilers, which were five in number, worked at 100lbs. pressure, and were 30ft. by 8ft., and fitted with Hopkinson high and low water safety valves. In the underground workings in the Chisnall seam there was a pair of quadruple ram pumps with 26in. cylinders, 10in. rams, 36in. stroke, fitted with high pressure condenser. The rising main was 170 yards, and the quantity of water raised about 570,000 gallons per ten hours pumping.

After the round of inspection, in the course of which most of the members descended either one or other of the shafts, the party were entertained at luncheon by the colliery officials, and then returned to Wigan, where they sat down to tea at the Victoria Hotel.

Mr. Henry Hodgson, President of the Association, briefly proposed a vote of thanks to Messrs. Pearson & Knowles, and the General Manger, Mr. John Knowles, for the facilities they had afforded the members for inspecting these modernly laid-out collieries.

The proposal having been most heartily adopted by the members, Mr. Knowles, in responding, said it had been a great compliment and honour for the company to receive the members of that Association at their Coppull colliery. He might add that the great strides which had been made in connection with mining operations during the last few years, both in the introduction of improved forms of safety lamps and the introduction of high explosives in place of gun-powder, had largely contributed towards the immunity from accidents, which was now so general. In fact, he might say that from the above two causes alone the risk of death had been reduced quite 90 per cent., whilst in addition there had been greatly increased protection of property. Indeed, he might say that under the present conditions there was no more danger in descending a colliery than in riding in a railway carriage.

VISIT TO BLACKBURN: Messrs. YATES & THOM'S WORKS.

On Saturday, June 23rd, the members of the Association paid a visit to the works of Messrs. Yates & Thom, at Blackburn, which had been kindly thrown open for their inspection.

The party, which numbered about 150, were received at the Canal Foundry, which forms the main body of the firm's works, by Mr. W. Thom, principal of the firm, and several members of the staff, who conducted them through the various departments of the establishment, and explained the special features of interest in connection with the plant and general workshop arrangements. The total ground area occupied by the firm's works is about eight acres, and the main buildings, which were inspected on Saturday, cover nearly four acres, about half of which is devoted to the fitting and erecting departments, and the other half to the moulding and boiler shops. Each department is served by overhead travelling cranes, and the various buildings are lofty and well ventilated. The machine tools in use are all of modern design, suitable for both the heavier and the lighter classes of work, and electric driving is being gradually introduced. The firm are also engaged upon additional buildings for the purpose of extending the boiler and moulding departments, and which will be fitted with machinery and tools of the latest type, and new erecting shops, which will be equipped with powerful electric cranes, are also being built. Amongst the productions of the firm are steam engines of all sizes and kinds, including blast, winding and pumping engines, air compressors, boilers and general engineering and mill-wright work of all descriptions. In addition to the boiler department at the Canal Foundry they have a branch boiler works which was not visited on Saturday. The firm employ about 900 men. Amongst the work in hand at the time of the visit was a fine pair of vertical compound winding engines for South Africa, which were shown in course of erection. These had cylinders 35in. and 54in. diameter, 5ft. stroke, and were capable of safely developing 2,000 I.H.P. at their maximum speed of 80 revolutions per minute, and 140lb. steam pressure. A tandem compound horizontal engine, to drive 1,000 H.P. with 150lb. steam pressure, for a cotton mill in the district was also approaching completion. Other work in progress included a vertical compound engine of 500 H.P., to work with steam of 130lb. pressure, and a vertical compound pumping engine with cylinders 18in. and 36in. diameter, and 4ft. stroke. The boilers seen in course of construction were all of the Lancashire double flue type, for working pressures from 150lb. to 180lb. The riveting, it may be noted, is done by hydraulic power, which is also used in several of the lighter cranes throughout the shop.

At the conclusion of the visit the party had tea at the Old Bull Hotel, and before the return to Manchester a hearty vote of thanks was accorded to

Messrs. Yates & Thom for their kindness in throwing open the works for inspection, and for their hospitality.

The President (Mr. Henry Hodgson), in proposing the motion, observed that it was very good of the firm to allow competitors, as many of them were, to go through their works and see what they were doing. Mr. Thom had shown them everything he could, and it was not their own fault if they had not learned anything during the visit.

Mr. Thom, in responding, remarked that he considered it not only a pleasure, but an honour, to receive the members of the Manchester Association of Engineers at the works that afternoon, and he hoped the younger members in particular had seen something from which they could derive benefit. The works were not quite what they would build to-day if they were surrounded by green fields, instead of cottages and streets, but the firm had done their best to modernize and enlarge the works, and had endeavoured by alterations and the addition of new modern tools to bring them up to date.

VISIT TO LIVERPOOL: INSPECTION "OCEANIC."

The series of summer excursions arranged for the present season by the Association were brought to a close by a very interesting and enjoyable visit on Monday, the 23rd July, to the celebrated Royal Mail Steamship "Oceanic," which had been freely thrown open for inspection by Messrs. Ismay, Imrie and Company.

The party, which included Members of the Association and Lady Friends, numbered upwards of 200, and were conveyed by special saloon train from Manchester to Liverpool, and then by Overhead Electric Railway special train to the Canada Dock, where the Oceanic was berthed. On arrival on board the party were entertained to tea in the first-class dining saloon, and afterwards were allowed an unrestricted inspection of every portion of the ship, the state rooms and cabins, the kitchens, and the splendid engine rooms and other equipments of the vessel attracting special attention. Returning to Liverpool, the party sat down to tea at the Exchange Station Hotel. Mr. Henry Hodgson, the President, occupied the chair, and at the close of the proceedings proposed a hearty vote of thanks to Messrs. Ismay, Imrie & Company for their kindness, not only in affording an opportunity to the members for an inspection of the Oceanic, but also for the very generous provision they had made for the Members and their Lady Friends during the visit to the ship. Mr. Henry Webb seconded the proposition,

remarking that he was very pleased they had that day had an opportunity of inspecting in so complete and thorough a manner the largest ship afloat, and the vote of thanks, having been supported by Mr. Thos. Ashbury, C.E., was carried by acclamation. The party then returned by special saloon train to Manchester.

OBITUARY.

JOHN TAYLOR was elected an Ordinary Member of the Association in 1873, and was Vice-President in 1875, and President in 1876. Subsequently he filled various other offices of the Assocation.

For a considerable number of years he held an appointment with the firm of Langworthy Bros., Salford, and practically retired from active business in 1884.

Mr. Taylor always took a vigorous interest in everything appertaining to the Association, being especially desirous that new ideas should not in any way interfere with its original objects.

He died on the 11th September, and was interred at Kersal.

THOMAS DANIELS. By the death of Mr. Thomas Daniels, the Association has lost one of its greatest and most respected members, and certainly there are few who have worked more assiduously and consistently for its welfare, or have left behind them a more pleasing remembrance of their personality.

Mr. Daniels joined the Association as an Ordinary Member in 1871, and successfully filled the various offices of the Association. In 1893-4 he occupied the Presidental Chair, the duties of which he carried out with marvellous zeal and energy.

Though not a public man in the sense that he has filled any public office (to which he had often been invited), he was very widely known and respected, being the manager at Messrs.

Nasmyth & Wilson's engineering works, Patricroft, where seven or eight hundred men are employed. Some two or three months ago Mr. Daniels suffered from an attack of influenza, and before he had entirely recovered returned to his work, in consequence he sustained a relapse and complications arising succumbed on Tuesday, the 6th March, age 59.

As a Works' Manager and Director it would be impossible to bear too high a testimony to his ability and business qualities. He was thoroughly acquainted with the labour organisations and their systems, and remarkably tactful in the management of men, considering them as individuals and studying their temperament and capacities. He endeavoured to hold the scales of justice fairly between the employers and employed, and achieved what few can claim, for while retaining the confidence and esteem of the firm he was popular among the men. Never since his appointment as Manager has there been serious friction, he several times by his tact averted strikes, and the only stoppage at the Bridgewater Foundry during his connection with it was not a local one—the engineers' strike of two years ago. On this occasion he gave the men the greatest satisfaction by keeping every man's place open until the end of the dispute. Mr. Daniels was justly proud of the fact that for thirty years he never had a day's illness or arrived at his work late. He was at his work at six o'clock every morning until his health failed, and he frequently remarked that he must set the men a good example—the general should be the first in the field and last out.

His business career has been varied. He was a native of Stony Stratford, Worcester, and served his apprenticeship at Wolverton. This was followed by experience in Glasgow, Hull, and the Midland Railway Company's works at Doncaster; from there he went to the Worcester Engine Works where he was made foreman of the erecting shop. After being there some

time under Mr. Edward Wilson, he was appointed foreman of the erecting shops at Messrs. Sharp, Stewart & Co., Manchester, and in March, 1883, he received the post which he retained to the time of his death—Works Manager at Messrs. Nasmyth & Wilson's, and for the last four years a director.

Shortly after entering the service of Messrs. Sharp, Stewart & Co., he became a member of the Association.

Mr. Daniels was a distinguished Freemason, being Past Master of Bridgewater Lodge, of which he was also Treasurer last year; he is also a member of the more advanced degree of the Royal Arch of which he was first Principal. He was an Oddfellow of 35 years standing.

He was interred at the Southern Cemetery in the presence of many representative bodies, workmen and confreres from the Works, and a large number of members of the Association, which was officially represented by the President, Mr. H. Hodgson, the Past-President, Mr. H. Webb, and the Secretary, Mr. Hazelton.

At the Meeting of the Association the same evening the President referred to the sad event.

Votes of Condolence.

The President said two members had died during the week. One of them, Mr. Daniels, was a Past-President, and was well known to very nearly all of them. He had been a most useful and genial Member of the Association, and one whom they could ill spare. The other was Mr. Hilditch, who was not so well known as Mr. Daniels, but was still a useful member.

Mr. Henry Webb moved a vote of condolence with the widow and relatives of Mr. Daniels, and also a vote of condolence respecting the death of Mr. Hilditch. He was glad to have an opportunity of bearing testimony to the worth of the late

Mr. Daniels. He was a man they could not talk with on practical subjects without feeling that from his youth he had had his heart and soul in his business, and he would be greatly missed by the firm he was connected with. Mr. Daniels was greatly liked by his workpeople. He was one of those men who could get a great deal of work out of people and yet be very well liked by them. At their meetings Mr. Daniels had always, whenever he spoke, something practical to say, and he took a very great interest in the doings of the Society. In electing him to the Presidency the members had conferred upon him the highest honour at their disposal. Mr. Daniels would be sadly missed all round.

Mr. Thomas Ashbury, in seconding the motion, heartily endorsed what had been said by Mr. Webb. He had been associated with Mr. Daniels as far back as the "Sixties," and had always found him to be a man wrapped up in the interests of his profession, of great practical experience, and of singular geniality and magnetic influence. Under his manipulation even the dullest subjects became interesting, and at their meetings he had always something to say which was of a practical character and to the point. In him the Society had lost a very important member, and they would greatly feel his loss.

William Ridings Hill was elected an Ordinary Member in 1876, but took little prominent interest in the Association. He died the 3rd November, 1900.

Albert Birch was elected an Ordinary Member in 1886. He served his engineering training at Messrs. Joseph Adamson & Co., Hyde, subsequently being engaged with various other firms, and ultimately returned to Messrs. Adamson, with whom he was engaged at the time of his decease.

He died suddenly February 19th, age 43 years.

THOMAS HILDITCH was elected an Ordinary Member in 1894. He received his chemical training at Owens College, where he studied chemistry and the allied sciences from 1877 to 1881, finally being junior assistant to Sir Henry Roscoe. In 1881 he entered the laboratory of Sir J. Whitworth & Co., and in 1888 was made superintendent of the steel smelting department, which position he held at the time of his decease. He died suddenly on the 5th March, age 40.

JOHN CRAVEN joined the Association in 1880, as a Life Honorary Member.

Mr. Craven was the deputy chairman of Craven Bros., Ltd., Vauxhall Works, Manchester. These works, with whom the late Mr. Craven was associated for the last forty years, were established in 1853 by Mr. Greenwood Craven and Mr. William Craven, who is still living, and from very small beginnings the present works, the building of which was commenced in 1857, have gradually extended until the firm now employ upwards of a thousand hands, whilst further extensions are in preparation at Reddish, near Stockport, in the final completion of which the late Mr. John Craven took a very keen personal interest. Although Mr. Craven occupied no very prominent public position, either in connection with the engineering trades, political or local affairs, his genial character made him very popular, and he was held in the highest respect throughout the district. In the promotion of the Manchester Association of Engineers he took an active part, filling the post of Vice-President in 1881, and President in 1882, and it was largely owing to his energetic assistance and co-operation that the Association has, from a comparatively unimportant organisation attained its present prosperous position. Mr. Craven was also a member of the Iron and Steel Institute, and the British Association. In local matters, although at all times shrinking

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